The *INTEGRAL* Science Data Centre

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ABSTRACT

The INTEGRAL Science Data Center (ISDC) is the interface between the scientific payload of the INTEGRAL gamma-ray satellite and the astronomical community. This center will process INTEGRAL data, to the point where they can be meaningfully interpreted by scientists unfamiliar with the instrumentation, and provide the necessary support for the full scientific exploitation of these data. Astronomers of many different fields will be able to use INTEGRAL data, and multi-wavelength studies will be facilitated.

The sky at γ-ray energies is highly variable. At the ISDC a rapid preliminary analysis of the data will be performed to detect whether unexpected events have occurred in the INTEGRAL field of view. In case of a detection, the foreseen observation plan may be modified accordingly.

An ISDC software system will be developed to pre-process the satellite data, archive it together with the ancillary data necessary to understand the observations, process the data to obtain images of the sky, energy spectra of the sources and time profiles. The results of this analysis and the pre-processed data will be made available to the observers and stored in the INTEGRAL archive, where they will become public after one year.

1 INTRODUCTION

1.1 The *INTEGRAL* observatory and the ISDC concept

The International Gamma Ray Astrophysics Laboratory (*INTEGRAL*) is a medium mission selected in 1993 by ESA for launch in 2001. *INTEGRAL* aims at high resolution spectral observations and high angular resolution imaging of the γ-ray sky together with a broad coverage of the electromagnetic spectrum from 3 keV to 10 MeV. The two main *INTEGRAL* instruments are the SPI spectrometer and the IBIS imager. An X-ray and an optical monitors, the JEM-X and the OMC, completes the *INTEGRAL* scientific payload. These instruments are described elsewhere in this volume. *INTEGRAL* is an observatory type mission, with most of the observing time available to the astronomical community. These properties will make *INTEGRAL* one of the important tools of astronomy in general in the early years of the next decade and will contribute to the advance of many subjects of modern astronomy, from stellar nucleosynthesis and the study of the interstellar medium to extragalactic supernovae and active galactic nuclei.

As a consequence of these properties, it is expected that many astronomers in the world will use *INTEGRAL* data in their research. Most of these astronomers do not necessarily have a specific experience in γ-ray astronomy.

They will consider *INTEGRAL* as one of the several observatories they use in their research. In order to contribute to the efficient use of the *INTEGRAL* facility, it is therefore necessary to provide these users with *INTEGRAL* data in a form and with a support such that they will be able to make the best scientific use of the γ-ray information available. This has led to the concept of the *INTEGRAL* Science Data Centre (ISDC). The ISDC forms the interface between *INTEGRAL* and the community of users.

At the ISDC, the *INTEGRAL* data will be processed to a level at which users can pursue their scientific interpretation. The ISDC will make the *INTEGRAL* data and the results of its analysis available to the users and will store them in a format that will be easily accessible not only at the time of the mission but for a long period thereafter, thus ensuring that they will be available for unexpected searches and discoveries also after the end of the mission. The ISDC will provide the users of *INTEGRAL* with software and support to ease the exploitation of their data. The ISDC will also make a near real time analysis of the *INTEGRAL* data and inform the *INTEGRAL* project scientist of the occurrence of unexpected phenomena.

1.2 The ISDC consortium

For the first time, ESA delegated the responsibility of the mission science data center. The ISDC was proposed by a consortium of about 10 institutes. The ISDC was selected in 1995 and started the same year its activities in Geneva. The ISDC consortium is represented by the principal investigator, a team of co-investigators and associate scientists. The consortium provides the resources needed to develop and operate the ISDC.

This approach brings some additional difficulties when compared with a facility run by a single institute, including a more complicated organization and management. On the other hand, there is potential for an efficient and more science oriented operation, e.g., making use of the know how of the community, bringing together experience of different laboratories, promoting collaboration and close cooperation between the *INTEGRAL* instrument teams and the ISDC.

1.3 Science at the ISDC

The ISDC is a center in which astronomical research is performed, through the active research programs of its scientific members. The ISDC staff will also have the operational responsibility to spot unexpected events, such as transient sources, in near real time, and to suggest targets of opportunity for further observations.

2 THE ISDC MAIN TASKS

2.1 Time critical operations

The sky at gamma-ray energies is much more variable than at visible wavelengths. Many of the sources shine during limited periods of time and must be studied during these periods. As a consequence, the ISDC will perform a first analysis of the data within 10 hours from the time of data receipt. This analysis will be used to detect whether major events have taken place in the patch of sky observed by the *INTEGRAL* instruments. In case of a detection of new sources or of unexpected events, the ISDC will transmit a target of opportunity alert to the *INTEGRAL* project scientist which may, when appropriate, modify the observation schedule accordingly.

The above task will be particularly important during the Galactic plan survey achieved during the core program. Every few days, *INTEGRAL* will scan a large fraction of the Galactic plan, with the primary goal of finding transient sources.

The results of this fast analysis will also allow to check that the observations proceed normally. In case of strong discrepancy between these preliminary results and the expectations, ISDC will inform the *INTEGRAL* project scientist, which may decide to modify the observation plan.

The feasibility of detecting and localizing Gamma-Ray Bursts within seconds is under study. The idea is to send alerts to other subscribing observatories while the GRBs are still active in the gamma-ray domain, and thus to achieve multi-wavelength observations of these mysterious events.

2.2 Instrument monitoring

The ISDC will monitor on-line critical instrument parameters and count rates to check the health of the scientific instruments on board *INTEGRAL*, and to detect peculiar observing conditions (e.g., Solar flares) or possible real bursts of the observed astronomical object.

The instrument characteristics, such as background and sensitivity characteristics, will be monitored off-line in order to build a description of the temporal evolution of the instrument behavior.

2.3 Standard analysis

After receipt and pre-processing of the telemetry stream, the ISDC will perform a set of standard data analysis operations, including data calibration and selection, background and instrumental response determination, data deconvolution, and, possibly, model fitting. The final results of this standard analysis will at least consist of sky images, source spectra and light curves, as well as data products at different processing levels.

2.4 The *INTEGRAL* archive

The data collected in the frame of a specific mission are often used in various research projects, sometimes many years after the end of the missions. In order to provide easy access to the *INTEGRAL* data, the ISDC will build an archive which will be remotely accessible through a computer network. This archive will include the original data in a format that is easily transportable as well as the results of the standard analysis of the data, including data at different processing levels. The archived *INTEGRAL* data will become public after one year.

2.5 Off-line analysis and users support

Although the best possible choices of algorithm and parameters will be used in the standard data analysis, users may want to repeat the data analysis with different choices, better adapted to their particular scientific goals. The ISDC will provide the support required to allow the users to carry out their own customized data analysis.

The ISDC will supply to the users data at different levels of processing, including images, source spectra and light curves. It will also provide software, documentation, and expertise for the more advanced data analysis. The ISDC will provide an ISDC guide, observation catalogues, data and software guides, and analysis cook-books. Users will be invited to carry out their data analysis at the ISDC in Geneva, where they will receive support.

The ISDC may also make available, for external observers and software developers, a portable analysis system (on selected operating systems), and/or provide remote processing functions within the ISDC system.

2.6 Observation simulators

An observation simulator will be built to allow scientists designing proposals to estimate the signal-to-noise ratios that can be achieved in a given observing time, and for a given (model) cosmic source by taking into account the expected background and the instrument efficiency. This simulator may also be used to assess the technical feasibility of observer proposals.

3 The ISDC software system

3.1 Basic concepts

The ISDC is developing only one software system which will support all the above ISDC tasks, for the data originating from the four different *INTEGRAL* instruments. The programs necessary to perform the operations will be designed in a very modular way and be based to a large extent on instrument specific software modules provided by the instrument teams. They will be linked together in chains performing one step after the other. It is expected that the same programs can be used in chains (pipelines) of varying complexity. These pipelines will correspond to the different uses of the software, say in the "standard analysis" or in the "off-line analysis". The pipelines will be written in a high-level interpreted language which will call a number of software modules.

This approach will make a very flexible system, which will facilitate the upgrade of software modules expected to be produced as a better knowledge of the in orbit instrument performances and of the analysis techniques are gained. It will also help users to customized their off-line science analysis.

3.2 *INTEGRAL* instrument team contributions

Gamma-ray instruments are complex and the data reduction and calibration rest on a detailed knowledge of the instruments. The *INTEGRAL* data analysis will therefore be based on instrument specific software modules written by the teams developing and building the instruments. These modules will then be integrated into the ISDC software system. All the analysis systems of the four instruments will use the same ISDC elements (communication standard, user interface, database(s) and related access routines, mathematical libraries, data display and manipulation facilities, etc...). The ISSW will consist of many different programs dedicated to single specific tasks. These modules will communicate mainly by exchange of their input/output and will be integrated into pipelines to accomplish more complex processing. The modular design will allow use of the same ISSW elements whenever possible, avoiding duplications, and facilitating the integration of the ISSW into the ISDC system.

A close cooperation is foreseen between the ISDC team and the instrument teams to ensure that the ISDC system is based on the best available ISSW algorithms as the mission evolves.

3.3 ISDC status and development plan

The ISDC has started its activities in 1995, and is located close to the Geneva Observatory in a building complex named Ecogia. Close relations between the ISDC and the Observatory ensure that the ISDC is in an intellectually lively environment. The Observatory, on the other side, benefits from a new center in a very active field of astronomy.

The ISDC team currently has a staff of some 10 scientists and engineers. This staff will increase to about 30 at the time of launch. The staff will be located in Geneva for most of the development time and for all the operational phase of the mission.

The development of the ISDC software system follows the formal ESA standard (ESA PSS-05), and extents over the next 3-4 years. Part of the system shall be ready mid-1999 to support ground calibration activities, while the whole system shall be ready in the year 2000 about one year before launch. The ISDC system will be used during the *INTEGRAL* flight time, possibly extending over 5 years, while the *INTEGRAL* archive shall be operational over an indefinite time scale. Such relatively long operational time scales impose some portability and maintainability constraints on the ISDC software system.

Additional information on the different elements of the ISDC may be found in the ISDC World Wide Web pages. The ISDC home page is at the following URL

`http://obswww.unige.ch/isdc`