INTEGRAL

Science Operations Centre

Announcement of Opportunity for Observing Proposals (AO-6)

Mission Overview, Procedures and Policies

INT/OAG/08-0297/Dc

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1 Introduction

1.1 Purpose of this document

This document fulfils two purposes. Firstly it introduces the INTEGRAL satellite with brief descriptions of its orbit, instruments, observation modes and ground system. Secondly, it describes the procedures to be followed by observers preparing INTEGRAL observation proposals, and the policies followed by ESA in handling proposals, from their submission to their evaluation.

1.2 Schedule and scope for AO-6

The schedule for INTEGRAL AO-6 is as follows:

- **10 March 2008: release of INTEGRAL AO-6**
- **18 April 2008, 14.00 CET (13.00 GMT): deadline for proposal submission**
- **19–22 May 2008: INTEGRAL Time Allocation Committee (TAC) meeting**
- **16 August 2008: Formal start of AO-6 programme.**

This AO is primarily intended for scientists of the ESA Member States and countries participating in INTEGRAL (Russia, USA, Czech Republic and Poland), but proposals from other countries will also be considered by the Time Allocation Committee.

Scientists from institutions in the United States are welcome to respond to this AO either as Principal Investigators or as co-Investigators on non-US proposals. Accepted US investigators should request funding from NASA via a separate solicitation.

1.3 Overview of the call for proposals

This call for INTEGRAL proposals consists of all the relevant documentation, a proposal generation and submission tool, and other software to help assess the visibility of a target and estimate the observation time required to meet specific scientific goals.

Here is the list of the available supporting documents:

- *"Mission Overview, Procedures and Policies"* (this document)
- *"IBIS Observer's Manual"*
- *"SPI Observer's Manual"*
- *"JEM-X Observer's Manual"*
- *"OMC Observer's Manual"*
- *"AO-6 Key Programmes and Associated Observations"*
- *"AO-6 Data Rights"*
- *"AO-6 Observation Tools Software User Manual"* (describes the use of PGT, OTE, TVP)

All these documents are available from ESA's INTEGRAL Science Operations Centre (ISOC) web page: http://integral.esac.esa.int/, where observers can also find links to download the Proposal Generation Tools (PGT), and access the Observing Time Estimator (OTE) and the Target Visibility Predictor (TVP). Note that OTE and TVP run remotely over the web, whereas PGT needs to be installed locally.

1.4 Extended mission and future AOs

The nominal operational mission began on December 16, 2002, two months after the launch, and lasted 24 months. Therefore, the nominal mission ended on December 16, 2004. The extended mission is currently approved by the Science Programme Committee (SPC) until December 31, 2012, and will be subject to a further scientific review in the Fall of 2009.

1.5 Available observing time

AO-6 will last 12 months from August 16, 2008 until August 15, 2009. As in previous cycles, approximately 24 Ms of observation time is available for this sixth cycle of INTEGRAL operations. Scientific observing time will be used almost entirely for Open Time observations of the General and Key Programmes. A small amount of Guaranteed Time (1.8 Ms) will be used for Core Programme observations.

Of the total 24 Ms of available observing time, the six accepted Key Programmes make up a total of 12 Ms; the Core Programme makes up 1.8 Ms (see §3.1.4); the uncompleted observations from AO-5 carried over typically amount to 1–2 Ms; and the total of 12 revolutions of SPI annealing per year amount to 2.4 Ms during which observations using SPI as the main instrument are not carried out. Therefore, there will be a total of 6–7 Ms of Open Time available.

1.6 AO-6 Key Programme

The concept of an INTEGRAL Key Programme (KP) was introduced for the first time in AO-4. Key Programme AOs are distinct from the standard announcement of opportunity. A Key Programme is intented as a means to carry out scientific investigations requiring a significant fraction of the total observing time of an AO cycle but also accommodating various scientific aims. A Key Progamme can be presented as a "multi-year" proposal and extend over several AO cycles. As mentioned above, there are six accepted KPs in AO-6. Details are provided in the document *"AO-6 Key Programmes and Associated Observations"*.

2 The INTEGRAL Mission

2.1 Overview of the mission

The INTErnational Gamma-Ray Astrophysics Laboratory was successfully launched with a PROTON rocket from Baikonour in Kazachstan on October 17, 2002 at 04:41 UTC. INTEGRAL is a gamma-ray mission sensitive between 3 keV and 10 MeV, whose payload consists of two main gamma-ray instruments, the imager IBIS and the spectrometer SPI, and two monitors, JEM-X (3−35 keV) and OMC (optical V-band, 500−600 nm). The IBIS and SPI instruments both have a large field of view (FOV; 29°×29° to zero response), simultaneously cover a broad energy range (15 keV to 10 MeV), and their design and function are complimentary. In addition, a particle radiation monitor measures charged particle fluxes on the spacecraft.

The scientific goals of INTEGRAL are reached by means of its high resolution spectroscopy allowing spectral line studies, combined with fine imaging and accurate positioning of celestial gamma-ray sources allowing their identification with counterparts at other wavelengths. Moreover, these characteristics can be used to distinguish extended emission from point sources and thus provide considerable power for serendipitous science: a very important feature for an observatory-class mission. Here is a list of scientific topics addressed by INTEGRAL:

i) **Compact Objects:** *white dwarfs, neutron stars, black-holes, high energy transients and GRBs*.

ii) **Extragalactic Astronomy:** *AGN, Seyferts, blazars, galaxies and clusters, cosmic diffuse background*.

iii) **Stellar Nucleosynthesis:** *hydrostatic nucleosynthesis (AGB and WR stars), explosive nucleosynthesis (supernovae and novae)*.

iv) **Galactic Structure:** *mapping of continuum and line emission, ISM, cosmic-ray distribution*.

v) **Galactic Centre:** *cloud-complex regions, mapping of continuum and line emission, cosmic-ray distribution*.

vi) **Particle Processes and Acceleration:** *trans-relativistic pair plasmas, beams, jets*.

vii) **Identification of High Energy Sources:** *unidentified gamma-ray objects as a class*.

viii) **Unexpected Discoveries**.

More details about the INTEGRAL spacecraft, instruments and scientific aims can be found in A&A Vol. 411 (2003). This is a special issue dedicated to INTEGRAL.

2.2 The INTEGRAL spacecraft and its orbit

The INTEGRAL spacecraft has two main components: the *payload module* and the *service module*. The payload module comprises the instruments with which the observations are performed. The service module provides the necessary infrastructure for the payload module. This includes functions such as attitude control and communication with the ground stations. Below is a detailed description of these.

2.2.1 The service module

The service module of the INTEGRAL spacecraft is a re-build of that developed for the XMM-Newton project and is composed of the following key sub-systems:

- **Mechanical Structure:** Consists of the primary structure (central cone and shear panels) supporting the launch loads, and one carrying the sub-system units and the tanks.
- **Thermal Control System:** Consist of active and passive thermal controls.
- **Attitude and Orbital Control Subsystem (AOCS):** Provides control, stabilisation, and measurements about the three satellite axes. This is done using star and sun sensors for primary attitude measurements and Reaction Wheels for torque actuation and momentum storage. The AOCS also controls the Reaction Control System; its thrusters provide the ability to dump momentum from the reaction wheels for orbit maintenance. A hard-wired Emergency Sun Acquisition Mode is implemented to acquire a safe Sun-pointing attitude in case that an AOCS failure results in uncontrolled attitude conditions.
- **Electrical Power System:** Regulates the function of power generation (solar arrays), storage (batteries), control and conditioning, distribution of the required power on a regulated 28 V main and redundant power bus.
- **Radio Frequency Function:** Ensures permanent up and down link of tele-commands and telemetry using a quasi omni-directional antenna and two redundant, S-band transponder.
- **Data Handling System:** Provides the ability to acquire, process and format data for the downlink. It consists of a single failure tolerant Command and Data Management Unit (CDMU – the central on-board computer) and two Remote Terminal Units: one on the service and the other on the payload module. These are used for data acquisition from peripheral units. Spacecraft telemetry is down-linked in real-time; there is no on-board data storage. Early in the mission after it was confirmed that the link RF margin was sufficiently large, it was decided to increase the telemetry clocking frequency and thus to increase the bit rate by ~25%. The rate for science data was increased from 86 to 108 kbps.
- **Launcher Adapter:** A special adapter including the separation system that provided the connection of the service module with the Russian PROTON launcher.

2.2.2 The payload module

The INTEGRAL payload module consists of an equipment platform accommodating the detector assemblies and an empty box supporting the “upper floor” at a height of about 3.2 m on which the coded masks are fixed. The detector bench provides the interface to the service module cone upper flange and carries SPI, IBIS and the relevant electronics and data processing units. System units (Payload module power distribution unit and remote terminal unit) are accommodated on the lower side. The vertical panels carry the OMC, the IBIS calibration unit and lead shields, as well as the star trackers, while providing support for the IBIS mask and the JEM-X mask support panel. Sun acquisition sensors (part of AOCS) are accommodated on dedicated brackets. The detailed instrument descriptions can be found in the instruments’ observer’s manuals.

2.2.3 The orbit

INTEGRAL follows a highly elliptical 72-hour orbit with an apogee of 150200 km and a perigee of 12500 km. There is drift of the orbital parameters in time. For example, the perigee of 9050 km in November 2002, increased to 12500 km over the course of four years, and the apogee evolved from 153600 km to 150300 km in the same period. The inclination has increased continuously from 52^{o} in November 2002 to 85^{o} in December 2007. Still, 65 hrs of the 72-hour orbit are spent above 40000 km.

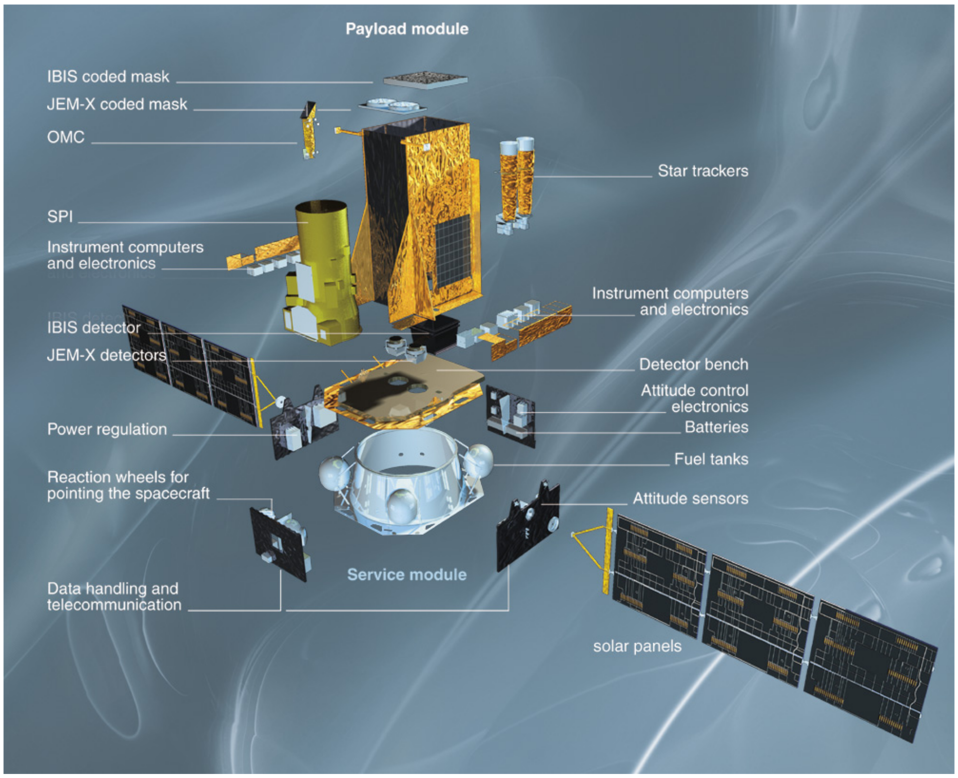

Figure 1: Exploded view of INTEGRAL service and payload modules

In order to allow for undisturbed scientific measurements and guarantee maximum science return, it is required to optimize the time spent outside the Earth's radiation belts. The real-time nature of the INTEGRAL mission requires full ground station coverage of the operational orbit above 40000 km with maximum use of available coverage below.

Generally, scientific observations can be carried out if the spacecraft is at an altitude of at least 40000 km, but the on-board radiation environment monitor can be used to adjust this limit. Scientific observations are currently performed between an altitude of 40000 km (ascending leg of the revolution) and 60000 km (descending leg of revolution). Instrument operation is interrupted in case of a higher radiation environment, e.g., during a strong solar flare.

Ground station coverage of the orbit above 40000 km is achieved by the combined use of the Redu (ESA) and Goldstone stations (NASA DSN) that offer simultaneous coverage during a large part of the orbit. The requirement for maximum visibility from ESA's European ground stations imposes a high inclination angle and an apogee position in the northern hemisphere. For critical operations like orbital manoeuvres, simultaneous coverage from two stations is required.

The satellite requirements on the orbital scenarios are dictated by power consumption, thermal and operational considerations. In order to guarantee sufficient power throughout the mission, the Solar Aspect Angle (SAA) is currently constrained to ± 40°. This implies that the pointing angle of the spacecraft must be greater than about 50° away from the Sun and the anti-Sun. The maximum duration of eclipses (umbra plus penumbra) cannot exceed 1.8 hours due to thermal and energetic constraints.

2.3 Overview of scientific instruments

Table 1 is a schematic summary of the complimentary features of the instruments on INTEGRAL, and Tables 2 and 3 list the key performance parameters of the payload. For more details on the instruments, please refer to the appropriate instrument Observer's Manuals.

Table 1: INTEGRAL science and payload complementarity.

Instrument	Energy range	Main purpose
Spectrometer SPI	18 keV - 8 MeV	Fine spectroscopy of narrow lines
		Study diffuse emission on >1° scale
Imager IBIS	15 keV - 10 MeV	Accurate point source imaging
		Broad line spectroscopy and continuum
X-ray Monitor JEM-X	3 - 35 keV	Source identification
		X-ray monitoring of high energy sources
Optical Monitor OMC	500 - 600 nm (V-band)	Optical monitoring of high energy sources

Table 2: Key parameters for SPI & IBIS

	SPI	IBIS
Energy range	18 keV – 8 MeV	15 keV - 10 MeV
Detector	17 Ge detectors [1] (6×6×7 cm^3), @ 85K	16384 CdTe detectors (4×4×2 mm^3), 4096 CsI dets (8.55×8.55×30 mm^3)
Detector area (cm^2)	500	2600 (CdTe), 3000 (CsI)
Spectral resolution (FWHM)	3 keV @ 1.7 MeV	8 keV @ 100 keV
Field of View (fully coded)	16° (corner to corner)	8.3° × 8.0°
Angular resolution (FWHM)	2.5° (point source)	12'
Source location (radius)	< 1.3° (depending on source strength)	30"@100 keV (50 σ source) 3' @100 keV (5 σ source)
Absolute timing accuracy (3σ)	~130 µs	~90 µs
Mass (kg)	1309	746
Power [max/average] (W)	385/110	240/208

[1] There were 19 active Ge detectors at launch. One died in Dec 2003, and a second in July 2004.

Table 3: Key parameters for JEM-X & OMC

	JEM-X	OMC
Energy range	3 keV - 35 keV	500 nm - 600 nm
Detector	Microstrip Xe/CH_4-gas(1.5 bar)	CCD + V-filter
Detector area (cm^2)	500 for each of the two JEM-X detectors	CCD: (2055 × 1056) pixels Imaging area: (1024 × 1024)
Spectral resolution (FWHM)	2.0 keV @ 22 keV	--
Field of view (fully coded)	4.8^o	5.0^o × 5.0^o
Angular resolution (FWHM)	3'	23"
10σ source location (radius)	1' (90% conf., 15 σ source)	2"
Absolute Timing accuracy	~1 ms	> 3 s
Mass (kg)	65	17
Power [max/average] (W)	50/37	26/17

The investigative power of the INTEGRAL observatory is best illustrated by showing how we can obtain scientifically valuable information from all the high-energy instruments simultaneously. Figure 2 presents the spectrum of the Crab, made with the latest version of the software (OSA 7.0), and calibration and configuration files.

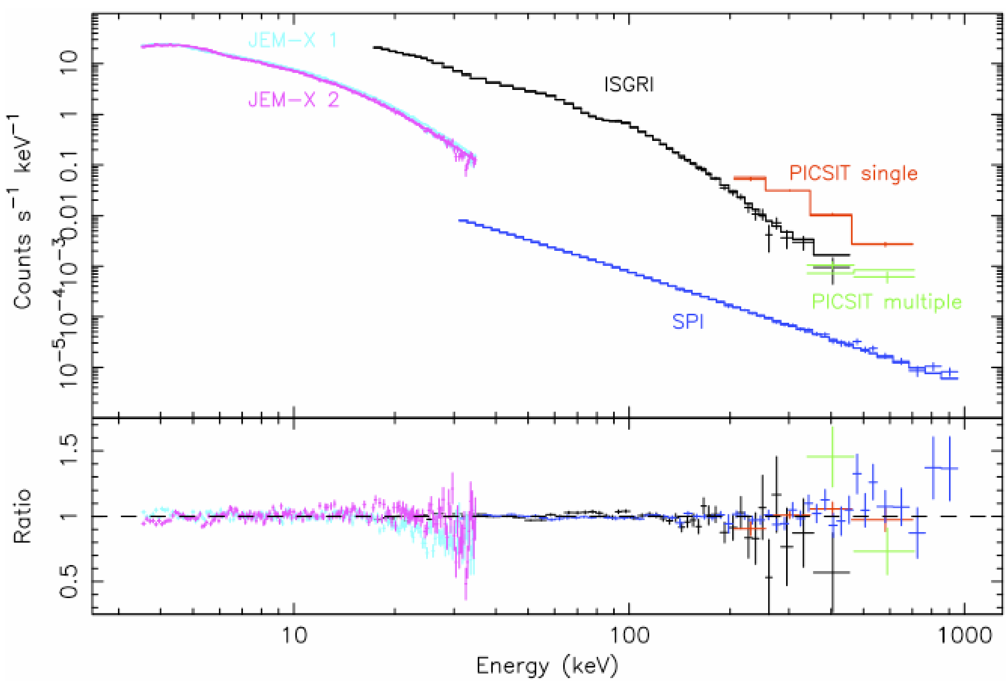

Figure 2: INTEGRAL Crab spectrum with JEM-X, IBIS and SPI. The model was taken from the [ISDC Newsletter No. 21](), and results from a fit on ISGRI and SPI data only. We added the JEM-X and PICSIT spectra.

2.4 Overview of INTEGRAL observation modes

Table 4 summarises the observation modes available for each instrument. Those shown in italics are used in exceptional circumstances only. More details are given in the relevant "*Instrument Observer's Manual*" and should be consulted especially in the case of JEM-X, where the operation strategy had to be adjusted for operations with one of the JEM-X cameras.

Table 4: INTEGRAL observing modes

Instrument	Modes
SPI	Photon-by-photon
IBIS-ISGRI	Photon-by-photon
IBIS-PICSIT	Histogram
JEM-X[2] (Modes in italics are for special circumstances only)	Full Imaging *Restricted Imaging* *Spectral Timing* *Timing* *Spectrum*
OMC	Normal *Fast*

[2] Only JEM-X 1 of two JEM-X detectors is currently used.

3 Observing with INTEGRAL

3.1 Overview and observation types

Since the four instruments on-board INTEGRAL are co-aligned (Figure 1) and operated simultaneously, observers generally receive the data for all instruments together with auxiliary data including that of the particle radiation monitor from the INTEGRAL Science Data Centre (ISDC, see §4.4). Typical observations can last from ~1 day to a few weeks, and proposals may contain several observations.

There are four classes of observations that can be applied for in the open time of the General Programme: *Standard*, *Fixed Time*, *Target of Opportunity* (TOO), and *Key Programme* (KP) associated observations. Core Programme and Calibration observations constitute another kind that cannot be applied for in the open time. Each class has implications for science operations and are described in detail below.

The introduction of Key Programmes allows deep exposures to be accommodated in the observing programme and following a recommendation by the INTEGRAL Users Group, proposals requesting long (>= 1 Ms) exposures should **not** be submitted in response to this open time AO-6. Instead, they should be submitted in response to an INTEGRAL AO for Key Programme observations[3]. This does not apply to TOO and fixed time proposals which may be submitted in response to this AO-6. If, however a proposer decides to submit a long exposure proposal in response to this AO-6, the proposal must include a detailed justification for the open time designation. It should be noted that proposals which duplicate already selected KP programmes for AO-6 will not be approved.

3.1.1 Standard observations

Standard observations are the majority of scientific observations. They do not require any special boundary conditions, e.g., constraints on sky visibility. This type of observation allows for the most efficient scheduling.

3.1.2 Fixed time observations

Fixed Time observations have special scheduling requirements. For example, phase-dependent observations of a binary system, or coordinated multi-wavelength observations would be part of this category. A sequence of observations separated by a time interval, e.g., three observations separated by two weeks, are also considered as fixed time observations. Such observations reduce scheduling efficiency since the spacecraft must be pointing towards a particular source at a particular time. The exact scheduling requirements for a fixed time observation may not be known at the time of proposal submission, but should be clearly stated in the proposal and flagged as such by setting the *Observation Type* to *Fixed Time* in the *Observation Details Panel* of PGT. Once the proposal is approved, ESA will contact the observer to determine the best time

[3] The next AO for KP observations with INTEGRAL is scheduled for release in November 2008, for observations during the AO-7 cycle of observations from Aug 2009 – Aug 2010.

to schedule the observation. Visibility constraints different than the usual biannual observation window for most sources, should be described in the scientific justification.

3.1.3 Targets of opportunity or TOO observations

"Target of Opportunity'' observations have very special scheduling requirements and are meant as a fast response to "new" phenomena, like outbursts of X-ray novae, AGN flaring, SNe, and high states of galactic micro-quasars. TOOs can be targeted towards known (e.g., 3C 279, GRS 1915+105, GRO J0422+32) or unknown sources identified by their probable class.

TOOs can have either internal or external triggers. Internal triggers come from the ISDC by screening the incoming science telemetry. External triggers are alerts based on observations with other observatories. All triggers are addressed to ISOC via the INTEGRAL TOO Notification Web page: http://integral.esac.esa.int/isoc/html/too/my_too_alert.html.

The Project Scientist (PS) decides on declaring a TOO observation, see *"AO-6 Data Rights"* for details. Implementation of the updated command schedule following ISOC's request will subsequently be performed by the Mission Operations Centre (MOC) in Darmstadt, Germany.

TOO observations require the interruption of the pre-planned schedule, re-pointing of the spacecraft and re-scheduling. They are, therefore, a very heavy load on the scheduling system and, like fixed time observations, reduce the mission's overall observation efficiency significantly. The typical response time from detection to re-pointing of the spacecraft is ~20 hours. Although neither the ISDC nor the ISOC have staff around the clock, the ISDC has an automatic TOO detection system and one on-call scientist outside working hours. Both the ISOC and MOC also provide an on-call service outside working hours including weekends and non-working days. Proposals for TOO observations can be made in response to this AO.[4]

In general, the following **rules and guidelines** are applicable to TOO proposals:

- The TAC is advised to accept no more than a few TOO proposals per year, all ranked according to their scientific merit from A to C.
- In contrast to previous AO's, the INTEGRAL Science Working Team (ISWT) has not included any TOO events as part of the Core Programme.
- A TOO will displace another observation if the latter can be rescheduled by the ISOC and MOC. In some cases, observations can be pushed back to the next AO round. KP observations are more difficult to displace given their importance and inherent difficulty in rescheduling.
- The proposer is responsible for requesting[5] the TOO when the trigger event occurs.
- The request is made by submitting a TOO Notification using the ISOC Target of Opportunity Alert Web page (see above). The PS or appointed deputy must include this request in the ISOC proposal database, allowing the tracking, documenting and time-line inclusion of TOO

[4] A ***proposal*** for a TOO observation can be submitted during the normal AO process, in anticipation of the event.

[5] A ***request*** for a TOO observation is understood to be made after a scientific event occurred which may justify such an observation. The occurrence of this event may or may not match an existing proposal.

requests, in the same manner as for the standard proposals accepted by the TAC during the AO cycle.

- The PS or an appointed deputy must decide to declare, or not, a TOO, by assessing whether the overall science of the mission will be enhanced by this TOO. It is possible that the TOO observation would conflict with a time-critical observation, another TOO (first one has priority) or other high priority observations. In such situations the PS will define the priorities and inform the scientific community of his decision about the TOO.

Gamma-ray bursts (GRBs) are considered as a subset of TOOs. GRBs occur randomly in time and space, therefore both inside and outside the FOVs of the instruments. Typically, one GRB per day is detected by SPI's anti-coincidence shield (ACS; see the "*SPI Observer's Manual*" and §4.5.2), and one per month is detected in the FOV. These data are found in the normal science data of the on-going observations and Near-Real-Time processing of the telemetry stream allows for prompt reaction and notification (see IBAS web page: http://ibas.iasf-milano.inaf.it/).

Due to the brevity of GRBs, no dedicated follow-up observations are done with INTEGRAL. Afterglow or counterpart observations with INTEGRAL are possible if: 1) the GRB occurs within the FOV of the on-going observation and will be covered during the on-going nominal dithering manoeuvres, or 2) if the event occurs outside the FOV but the spacecraft will dither onto that position during the nominal dithering manoeuvre of the observation during which the event occurred.

3.1.4 Core Programme Observations[6] of the Perseus Arm

Introduction

The INTEGRAL Core Programme (CP) will be terminated in December 2008, i.e. about 4 months after the start of the AO-6 cycle of observations (see Figure 3). The CP return for the ISWT for this period amounts to about 1.8 Ms assuming an annual science observing time of 24 Ms and a CP return of 20%. The ISWT has decided to spend this amount of time on observations of the Perseus Arm region, as described below.

Scientific Objectives

One of the key investigations performed by the INTEGRAL Observatory since launch has been the soft gamma-ray Galactic Centre Deep Exposure and the Galactic Plane Survey, successfully exploited to a depth of better than 1 mCrab in the central radian. The unprecedented sensitivity achieved in the gamma-ray domain over the approximately 900 square degrees FOV of the IBIS imager was confirmed by the discovery of the "new" soft gamma-ray sky so far populated with more than 400 sources belonging to all classes of Galactic sources plus extragalactic objects mainly of the Seyfert types. Currently, 25% of the discovered gamma-ray emitters are of unknown origin, with no counterparts at different wavelengths.

A common feature, in both the Galactic and extra-galactic context, is the exciting discovery that many of the new INTEGRAL sources exhibit a high degree of intrinsic obscuration. The discovery of these new families of systems has profound implications in the fields of stellar evolution and extra-galactic studies. The planned observations focus on the stellar aspects, both

[6] Text based on input provided by P. Ubertini (INAF/IASF-Roma), on behalf of the ISWT.

through observing discrete objects and their nucleosynthetic residue. By complementing the extensive survey of the Galactic centre region with a deep survey of the outer spiral arms, where the material is considerably less dense, we will be able to extend our present studies of compact objects through a detailed comparison of the relative populations of all classes of gamma-ray emitting Galactic types in the very different environment of these outer regions. A more complete understanding of our high energy Galaxy will be the result.

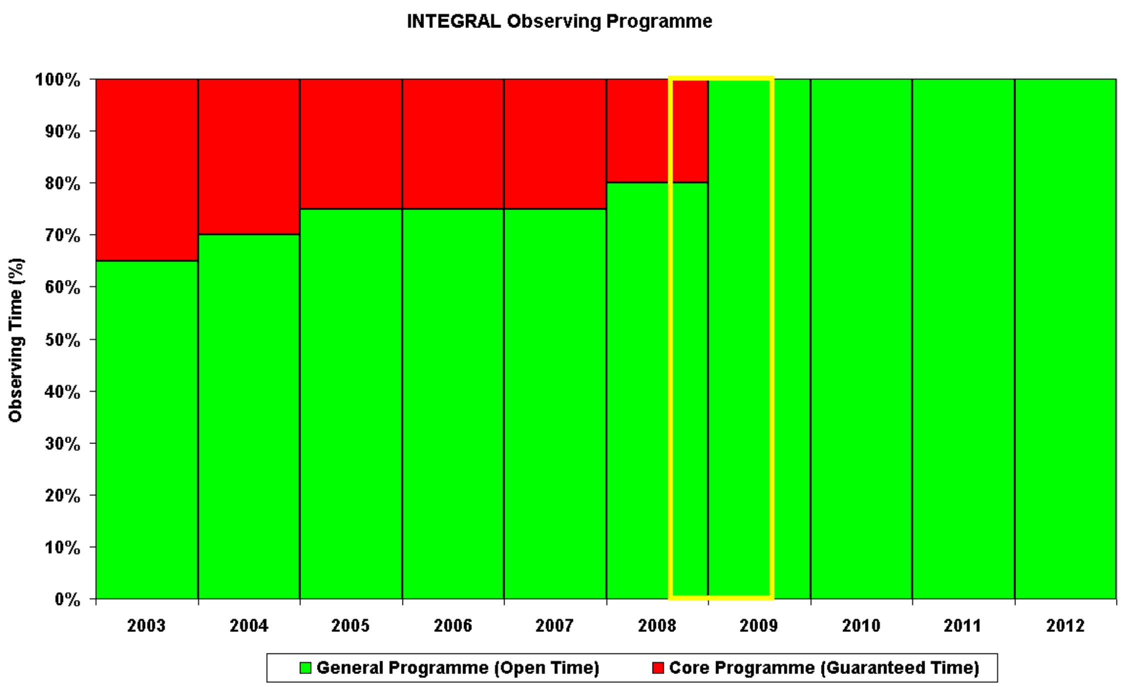

Figure 3: Breakdown of the INTEGRAL observing time as a function of time. Launch took place on 17 October 2002. The nominal mission began on 17 December 2002, the extended mission began on 17 December 2004. The time window covered by the AO-6 cycle of observations is indicated (yellow box). The termination of the Core Programme has been confirmed by ESA's Science Programme Committee in November 2007.

A homogenous exposure along the Galactic plane is crucial for imaging of the diffuse Galactic emission with SPI. Exposure contrasts introduce intensity contrasts in the resulting images, which make it difficult to disentangle faint diffuse emission features from exposure variations.

A particular important scientific question is related to the existence of 511 keV line emission from the Galactic disc. On theoretical grounds, faint 511 keV disc emission is expected from positrons ejected during radioactive decay of ^{26}Al, and faint disc emission have indeed been detected with SPI. Yet OSSE suggested considerably more emission from the galactic disc, and indeed, many plausible positron source candidates should also lead to substantial disc emission. Establishing the precise level of the Galactic disc emission using SPI should therefore be a primary scientific goal of INTEGRAL, in order to clearly identify the nature of the Galactic positron source. The observations that are proposed here will greatly help to improve the assessment of the disc emission, since they will allow to clearly separate exposure effects from diffuse faint emission.

The planned observations will also enhance our understanding of Galactic nucleosynthesis, in particular in the so far weakly studied outer part of our Galaxy. COMPTEL observations indicate the presence of ^{26}Al in one of the fields (around longitudes of 150°) as can be seen in 1.8 MeV all-sky images and also spectral analyses. It will be important to confirm if indeed recent nucleosynthesis has also taken place in such distant areas from the Galactic centre. In addition, the planned observations will nicely constrain the outer part (i.e. beyond the solar circle) of the radial ^{26}Al density profile, which provides important information on the metallicity dependence of Galactic ^{26}Al nucleosynthesis. The metallicity Z of the Galaxy varies as dlog(O/H)=-0.07 dex/kpc, which should leave an imprint on ^{26}Al if the yields scale with Z^n, where $n \approx 1$. For example, Wolf-Rayet nucleosynthesis models predict $n \sim 1.5$, so if Wolf-Rayet stars are indeed the primary source of galactic ^{26}Al, SPI should be able to measure the metallicity imprint of this source.

Finally, a deeper exposure in this outer region of our Galaxy should result in a number of new point sources, and re-confirm (or not) the existence of earlier claimed detections, e.g. the candidate ^{44}Ti source in the Per- OB2 region, indicated by early CGRO/COMPTEL work. Based on existing INTEGRAL catalogues and surveys, a breakdown of expected new sources from this region is provided in Table 5.

Table 5: Expected new source

Source Type	Proposed Region
HMXB	5
LMXB	2
SNR/PSR	2
CV	2
AGN/QSO	9
Clusters	3
Unclassified[7]	20
New IGR sources[8]	8-10

[7] Includes known sources for which the nature has not yet been determined.

[8] Sources discovered by INTEGRAL mostly in the direction of the spiral arms.

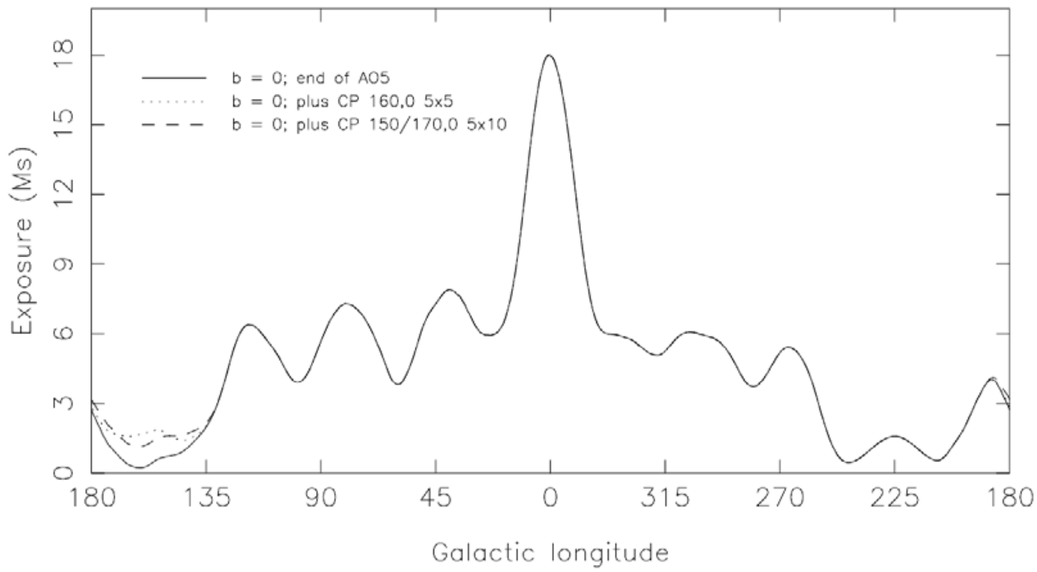

Figure 4: Longitude profile at Galactic latitude b = 0° (solid line, 1° wide) in the IBIS exposure map at the end of AO-5 (from launch up to August 2008). The minimum in exposure along the Galactic plane is at l = 160°. Two different exposure strategies have been tested (E. Kuulkers/ISOC, private communication), i.e. 5x5 at l = 160° (dotted line) and two 5x5 grids at 150° and 170° (dashed line). The 5x5 grid at (l, b) = (160°, 0°) gives the best coverage.

Observing Strategy

The goals of the planned CP observations can be achieved using a total exposure time of 1.8 Ms which results in 800 pointings of 2250 s each using a standard grid 5×5 at (l, b) = (160°, 0°) as shown in Figure 4.

Data rights

According to the INTEGRAL Science Management Plan, the data from the Core Programme belong to the ISWT for the usual proprietary period of one year after the data under consideration have been made available to the ISWT by the ISDC. Further details on scientific data rights, and TOO rules and guidelines are described in the current AO's *Data Rights* document.

3.1.5 Key Programme observations

The concept of Key Programme (KP) was introduced in §1.6. The document entitled "*AO-6 Key Programmes and Associated Observations*" contains all the details of the Key Programmes and assigned data rights approved during the AO-6 KP. For this standard AO, PIs may propose to get the data rights for point or extended sources that will be observed during a Key Programme. Such proposals should be flagged as associated with the particular KP in the manner outlined in §A.8. The PI will not have to give observation times and instrument modes for these proposals, but the proposal must still be submitted via the PGT together with a full scientific justification and technical feasibility.

3.1.6 Joint XMM-Newton and INTEGRAL observations

With the aim of taking full advantage of the complementarity of ESA's high energy observing facilities, both projects have agreed to establish an environment for those scientific programmes that require observations with both the XMM-Newton X-ray observatory and the INTEGRAL satellite to achieve outstanding and competitive results.

The issue of the XMM-Newton announcement of opportunity is separated by half a year from the INTEGRAL announcement of opportunity such that coordinated programmes can easily be proposed on the basis of observations accepted by one of the two projects.

By agreement with the XMM-Newton observatory, the INTEGRAL TAC may award up to 300 ks of XMM-Newton observing time for observations that are difficult to accommodate within the scheme described above:

- short (~10 ks) XMM-Newton observations simultaneous to long (>>10 ks) INTEGRAL observations
- short (~10 ks) snapshot-type XMM-Newton observations of newly detected and likely variable sources which require scheduling within one year after the INTEGRAL observation and subsequent detection.

Proposers wishing to make use of this opportunity will have to submit a single proposal in response to the INTEGRAL announcement of opportunity. Although time is requested on both observatories, it will be unnecessary to submit proposals to two separate review boards. A proposal submitted to INTEGRAL will be reviewed exclusively by the INTEGRAL TAC.

The primary criterion for the award of observing time is that both INTEGRAL and XMM-Newton data are required to meet the scientific objectives of the proposal. The allocated XMM-Newton time should not exceed the allocated INTEGRAL time. Neither TOO nor any other type of observations with a reaction time of less than 8 weeks from an unknown triggering date will be considered for this cooperative programme. Repeated observations are excluded from this joint programme.

It is the proposers' responsibility to provide a full and comprehensive scientific and technical justification for the requested observing time on both facilities. *The observation must be flagged as coordinated in PGT.*

Both projects, the XMM-Newton and INTEGRAL observatories, will perform feasibility checks of the proposals. They each reserve the right to reject any observation determined to be unfeasible for any reason.

Apart from the above, both missions' general policies and procedures currently in force for the final selection of the proposals, the allocation of observing time, the execution of the observations, and the data rights remain unchanged.

3.1.7 Nearby supernova as Target of Opportunity

Following a recommendation from the INTEGRAL Users Group it has been decided that the unique and highly important event of a nearby Supernova should be treated as a ToO observation with all its data to be made immediately public[9] to the scientific community at large. **Note that this decision implies that individual open time proposals for nearby Supernovae cannot be submitted in response to this AO.**

The observing strategy for a nearby Supernova is described in some detail below in order to inform the community about the selected approach to conduct the public INTEGRAL observations. This strategy has been defined by the IUG, using substantial input from Mark Leising (U Clemson/USA).

Definition

The term "nearby" is understood to describe the distance to a Supernova event that occurs in the Local Group up to a distance of:

1. 60 kpc (i.e. including LMC and SMC) for core-collapse SN (II, Ib, Ic)
2. 1 Mpc (i.e. including M31) for thermonuclear SN (Ia)

Introduction

The possibility of a nearby Supernova presents an exciting prospect for INTEGRAL. There is a significant chance of such an event during the extended mission operations phase. We might well learn more about that type of SN from this one object than all previous objects combined and INTEGRAL will be a key contributor to that knowledge.

The modeling of typical supernova explosions suggests that fluxes of brightest lines (e.g. 847 keV and 1238 keV lines of the ^{56}Co decay) are of the order of 10^{-3} photons s^{-1} cm^{-2} at the distances of 60 kpc and 1 Mpc for SNII and SNIa, respectively. At such high fluxes INTEGRAL is expected to deliver extremely valuable science. For SNII this means that a supernova in LMC and SMC would be an excellent target for INTEGRAL. For a type SNIa, an explosion in Andromeda is expected to be equally bright event for INTEGRAL.

Discovery

The method of discovery will depend on the SN type: *core-collapse* or *thermonuclear* explosion.

1. *Core-collapse SN*: Core collapse Supernovae (SN type II, Ib, Ic) will most probably release neutrinos escaping the collapsing system hours before the escape of photons. The Supernova Early Warning System (SNEWS, cf. P. Antonioli, 2004, New J. Phys. 6, 114, astro-ph/0406214) utilising a network of neutrino and gravitational wave detectors, notifies interested subscribers. ISOC has subscribed to the alert system at http://snews.bnl.gov/alert.html

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[9] The term "immediately public" means that general on-line access by the science community to the so-called "near real-time (NRT) data" at the ISDC will be provided by ISDC. The consolidated data, usually available few weeks after the observations, will be accessible via the public archives.

2. *Thermonuclear SN*: The discovery of Galactic SN of type Ia will probably be made in the visible regime if the event occurs at sufficiently high Galactic latitudes. These announcements are available via the IAU Circulars. At lower latitudes, first detection could be via X-ray or gamma-ray observations (GLAST Gamma-ray burst monitor, Swift, INTEGRAL), or eventually via radio emission. Again, results would be communicated to ISOC via IAUC, ATel, GCN or similar channels.

Follow-up observation strategy

The science objectives can be achieved through the observation of the time evolution of fluxes (light curves) and line spectroscopy. **It is important to observe the SN as soon as possible**.

The strategy for the first year after the event includes:

i) Observe the SN immediately and continuously for 40 days.

ii) If SN type Ia (thermonuclear): continue to observe for intervals of TBD[10] Ms duration at 50% duty cycle thereafter.

iii) If SN type II, Ib, Ic (core-collapse), continue to observe for 2 Ms at 33% duty cycle thereafter.

iv) Then, possibly, re-observe (re-point) the SN based on changes at other wavelengths (e.g. the onset of circumstellar interactions, seen in X-rays, radio, Hα) or based on results from INTEGRAL data themselves and as decided by the Project Scientist.

Note that item i) will be implemented regardless of the SN type. During the first 40 days of observations, the PS will reconvene with the IUG, and additional experts if required, to optimize and fine tune the strategy as laid out in items ii) to iv) as well as to devise a strategy for the long term (beyond first year). One also has to bear in mind the substantial diversity of supernova properties. It is not excluded that the observing strategy of a particular supernova will be optimized to maximize the science return from INTEGRAL.

Data Rights

Following a recommendation by the IUG, observations of Galactic SN shall be performed such that all data associated with the observations are made public immediately to the scientific community at large. This implies that the ISDC is requested to make these data publicly available with minimum delay. The NRT (Near-Real Time) data format currently in place for Key Programme observations will be suited for this.

3.1.8 Calibration observations

Dedicated payload calibration observations are occasionally executed during the normal operation phase. Observations of the Crab are usually carried out during every visibility period in order to continually monitor, assess and verify the scientific performance of the instruments. This helps to refine our knowledge of the instruments and thus our ability to characterise their

[10] TBD by the PS in consultation with the IUG and additional experts, if required.

performance. This is particularly important after annealing of the SPI detectors or after strong solar flare events.

An initial long Crab calibration observation took place in February 2003. Thereafter, typically up to one revolution per viewing period has been used for Crab calibrations. OMC flat field calibrations to characterise the instrument's response are performed ~1/month with a duration of ~4.5 hours. Performance verification of the spacecraft (e.g. AOCS calibration), are also performed regularly. Proposers should not duplicate such calibration observations in preparing open time proposals.

Public observations of the Earth were performed during AO-3. This allowed an accurate estimate of the cosmic X-ray background — an important and long-standing problem in high energy astronomy — while providing a better estimate of the instrumental background, which lead to improved background modelling.

Annealing of the SPI detectors is not a calibration per se, but it is intended to partially recover the gradual time-dependent degradation in energy resolution. These annealings are performed approximately every six months and last six revolutions (2.5 Ms).

3.2 Observation modes

There are three distinct observation modes: *rectangular dither*, *hexagonal dither* and *staring*. During all observations, the spacecraft provides stable pointings within 7.5″ of the pointing direction. The only mode suitable for deep exposures is the standard, rectangular 5×5 dither.

In order to minimize systematic effects due to spatial and temporal background variations in the IBIS and SPI instruments, **a controlled and systematic spacecraft dithering manoeuvre is required**. This manoeuvre consists of several off-pointings of the spacecraft's pointing axis from the target in ~2° steps. The integration time for each pointing (all instruments) on the raster is between 30 and 60 minutes, adjusted so that an integer number of complete dither patterns are executed. Two different dither patterns and the staring mode are used and described below. Note that the hexagonal dither pattern is implemented as it was in AO-4.

3.2.1 Rectangular dithering

Rectangular dithering on a 5×5 grid is the standard observation mode. It is well suited for observations characterised by a FOV containing multiple point sources whose positions are unknown. It is also well suited for observations of extended or weak sources that can best be studied by accumulating exposure time through a sum of individual pointings ("mosaic"). This observation mode should always be used as the default.

During AO-1 and most of AO-2, this mode consisted simply of a square pattern centred on the nominal target position, as shown in Figure 5. In this implementation, one pointing was with the source on-axis, and 24 other pointings with the source off-axis, each separated by ~2^{o} (currently 2.17) arranged on a rectangular grid. The roll angle between pointings was always 0^{o}.

Starting in AO-3, the pattern was optimised to reduce systematic effects in the IBIS images. This implies that for observations requiring several dither cycles, an offset between the centre of each dither cycle is introduced. This ensures that no pointing attitude is repeated over the course of the observation. Hence, the Centre Of dither Pattern (COP) moves around in a pre-defined manner during the course of an observation. The COP pattern is parallel to the original 5×5 dither and consists of 7×7 points centred on the target, with a step size of 0.3° (see Figure 5). Thus, the whole COP pattern fits within the inner 3×3 points of the original dither. The 49 points in the COP pattern allow for an observation time of 2.2 Ms without repetition of a given pointing.

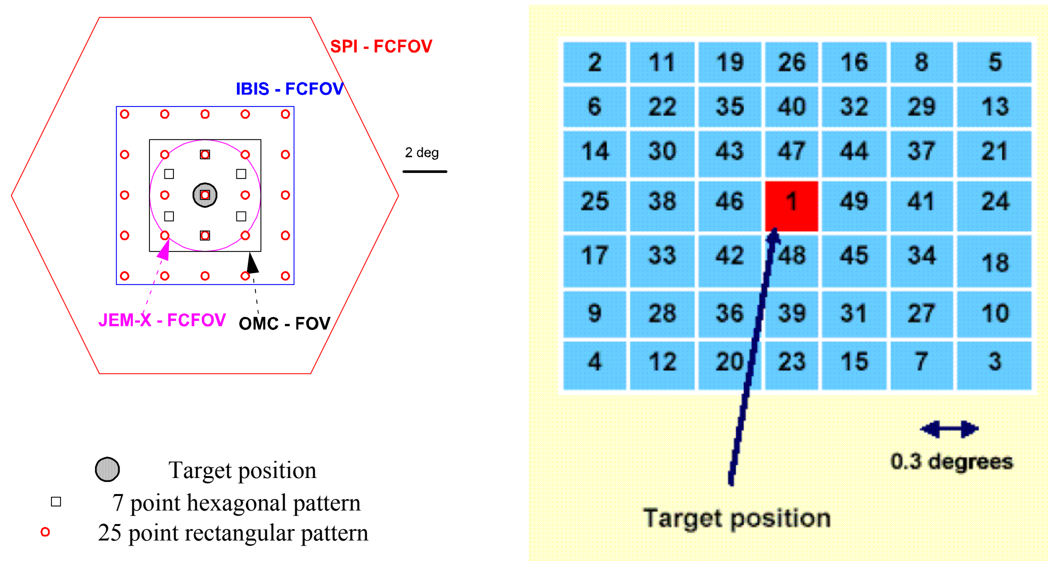

Figure 5: Schematic view of dithering patterns (left) and COP Offset Pattern for a 5x5 dither.

In addition to the moving COP, to further reduce systematic effects in deep mosaics, since June 2005 the orientation of the 5×5 pattern is set such that the axis of the dither pattern is rotated by 11.3° = arctan(1/5) with respect to the instrument axes. As the instrument axes depend on the relative position of the Sun, the exact dither pattern pointing directions depend on the time of execution of the observation.

The most recent optimization to reduce systematic noise in mosaics involves a stepping in roll angle, and was implemented for the first time at the end of November 2007 in revolution 624. With this strategy, the roll angle for an observation with N repetitions of the 5×5 pattern spans the range from +3° to -3°, in steps of dθ = 6/(N-1).

3.2.2 Hexagonal dithering

The use of this mode is strongly discouraged, for it seriously compromises the imaging capabilities of IBIS, SPI and JEM-X, rendering the data useless for use in large mosaics.

Hexagonal dithering consists of a hexagonal pattern centred on the nominal target position: one source-on-axis pointing, six source-off-axis pointings 2° apart, in a hexagonal pattern. This mode should generally only be used for a single point source whose position is known and where no significant contribution from out-of-view sources is expected. Earlier observations have shown that this is rarely the case because of bright or transient sources, and observers are generally discouraged from using this mode, except if their scientific goals require continuous monitoring of the main target by JEM-X. Such a strategy would however be at the expense of SPI data quality if there are even a few sources in the FOV (see the "*SPI Observer's Manual*").

This observation mode was altered in the middle of AO-3 (November 2, 2005) to allow for a wandering COP offset to the hexagonal dither pattern. This COP pattern consists of 2×6 points that define two hexagons (red dots in Figure 6), centred around the original centre point of the (blue) dither pattern.

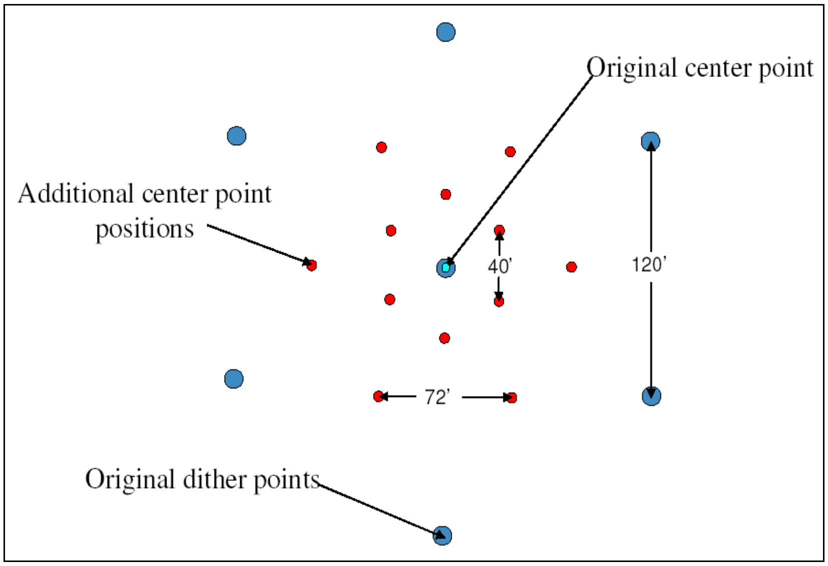

Figure 6: COP Offset Pattern for Hexagonal Dither Pattern.

3.2.3 Staring observations

The use of this mode is strongly discouraged, for it seriously compromises the imaging capabilities of IBIS, SPI and JEM-X, rendering the data useless for use in large mosaics. For this reason, staring observations must be very well motivated.

There are however circumstances that require long, uninterrupted, on-axis observations of a source, such as in studies of time variability or QPOs.

3.3 Amalgamation

INTEGRAL's primary instruments have large FOVs and generally show little off-axis degradation of sensitivity and resolution within the fully coded FOV. This implies that several sources can be observed simultaneously. ISOC, therefore, sometimes *amalgamates* (combines) several approved observations *into a single observation*, hence increasing operational efficiency, *while respecting the original goals of each observation*.

Amalgamation is the process by which several (independent) observations with similar attributes (sources in the same FOV, instrument configuration, etc.) are linked in the ISOC database, such that they are scheduled as a single observation: the *core* observation.

The following criteria and steps to create a proposed amalgamation are used by ISOC:

- After the TAC process, the proposal database is searched for amalgamation candidates.
- The mode of the core observation is that of the longest candidate observation.

- The duration of the core observation is defined according to the longest observation of the group. It may be lengthened to account for off-axis corrections and ensure that all sources are observed for a time consistent with their requested on-axis duration.
- The TAC's recommended scientific grade for a "core" observation will be as high as or higher than the grades of all observations in the amalgamated group.
- All sources are within the fully coded FOV for the main instruments (SPI, IBIS).
- The observation modes are identical for all four instruments (JEM-X: primary mode only), except when an observer has set "data not required" or deselected "prime" in the proposal.
- Fixed time observations cannot be amalgamated.

ISOC generates a list of possible amalgamations from the database of accepted proposals. It is then submitted to the PS for endorsement. Proposers are notified if their observations have been amalgamated. ISOC may de-amalgamate observations if necessary.

4 The INTEGRAL science ground segment

4.1 Introduction

The INTEGRAL science ground segment is constituted by the ISOC and ISDC, shown in the bottom part of Figure 7.

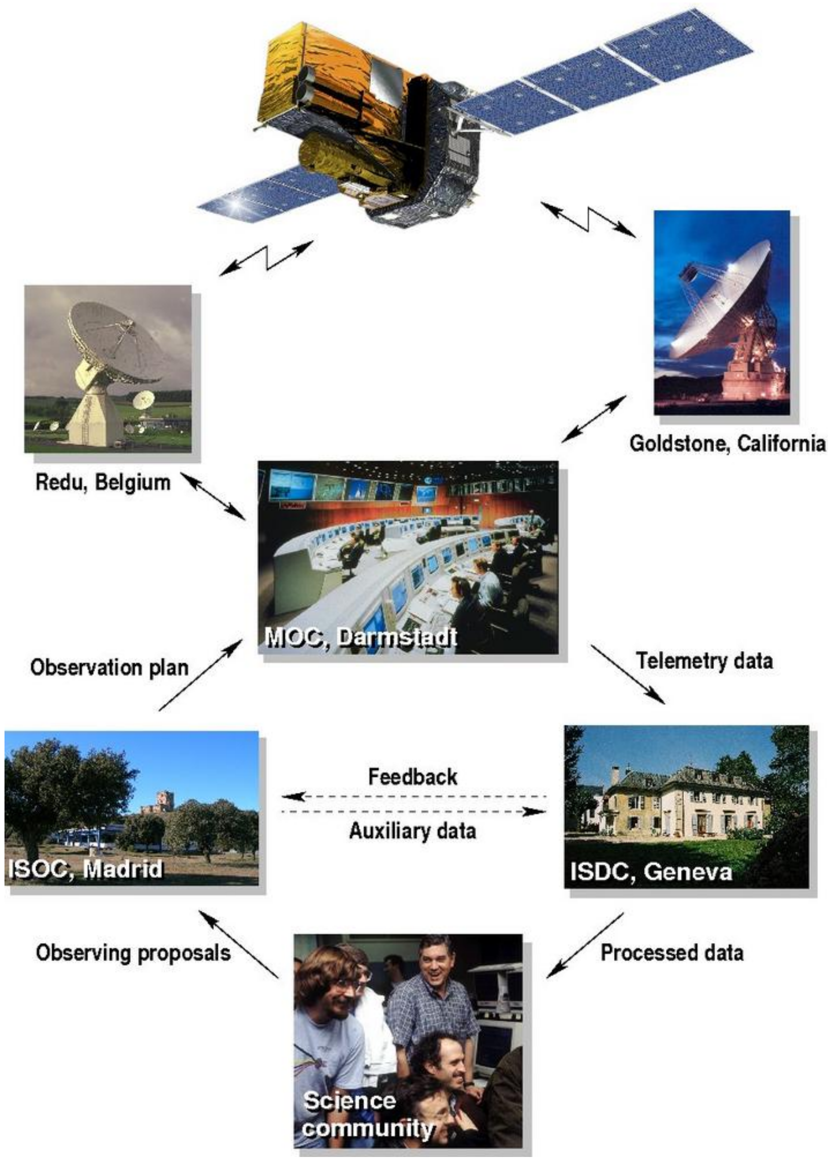

Figure 7: The INTEGRAL flight segment (upper half) and ground segment (lower half).

ISOC receives observation proposals and optimises the accepted ones into an observation plan consisting of a time line of target pointings together with the corresponding instrument configurations. The ISDC receives the science telemetry plus the relevant ancillary spacecraft data from the MOC, responsible for the operations of the spacecraft and payload. The ISDC processes these raw data, and generates standard data products that are distributed and archived. ESA also maintains a copy of this archive at the ISOC.

4.2 Science ground segment support for observers

The INTEGRAL ISOC web site at http://integral.esac.esa.int/ provides access to important information for proposers and observers. This includes:

- INTEGRAL Announcement of Opportunity
  - AO announcement key dates
  - AO documentation
  - Proposal support tools: Proposal Generation Tool (PGT), Observing Time Estimator (OTE), Target Visibility Predictor (TVP)
  - Links to (mainly high energy) astronomical catalogues.
- INTEGRAL Target and Scheduling Information
  - Scheduling Information
  - Long and short term scheduling
  - Approved Target List
  - ISOC & ISDC data archive.
- INTEGRAL Helpdesk and Frequently Asked Questions.

A helpdesk handles all questions related to the INTEGRAL mission (received via e-mail at inthelp@sciops.esa.int or submitted on the web from http://integral.esac.esa.int/helpdesk/). The helpdesk is organized such that questions relating to proposals, observation modes, scheduling and INTEGRAL in general, are handled by ISOC staff; questions about the data, analysis software, instrument calibration and data delivery are handled by ISDC staff. The sharing of this responsibility is transparent to users. A list of frequently asked questions (FAQ) is maintained on the ISOC and ISDC web pages.

The INTEGRAL science analysis software is available together with documentation and test data for download from the ISDC web page at http://isdc.unige.ch/index.cgi?Soft+download. Further information on ISDC user support is provided in §4.4.

4.3 From proposal to observation: ISOC

4.3.1 ISOC responsibilities

The INTEGRAL Science Operations Centre, ISOC (http://integral.esac.esa.int/), was relocated to the European Space Astronomy Centre (ESAC), Villafranca del Castillo, Madrid, Spain in early 2005. ISOC is responsible for the definition of scientific operations including instrument configuration for each observation, mission planning and implementation of the observing programme. A newsletter is published as a means to keep the INTEGRAL community informed (http://integral.esac.esa.int/newsletters/).

In summary, ISOC is responsible for:

- Preparing AOs, receiving the proposals, assessing their technical feasibility and transmiting the assessments to the TAC.
- Scheduling and implementing of the observing programme.
- Defining science related operations and instrument configuration for each observation.
- Receiving TOO alerts, and implementing the Project Scientist's decision in regards to the planning of an accepted TOO.
- Keeping an archival copy of all scientific data created and maintained by ISDC.

4.3.2 Proposals

Scientists submit proposals in response to an Announcement of Opportunity, issued by ESA/ISOC at regular intervals during routine, in-orbit operations. In general, proposals must reach ISOC before the AO deadline specified in the documentation. Requests to observe newly identified "Targets of Opportunity", however, can be submitted to ISOC at any time (see §3.1.3). Below, we briefly describe what proposals should contain, making a distinction between standard and Key Programme proposals.

4.3.2.1 Standard proposals

Standard observation proposals (< 1 Ms; see §3.1) must clearly contain: one or several well-defined targets, a description of the preferred instrument modes, the requested observation duration as entered in PGT, and the scientific justification. **All proposals must specify either IBIS or SPI as the main instrument**. The TAC evaluates each proposal primarily on the basis of its scientific merit, but obviously considers its feasibility and related technical issues. Two examples of observations that will normally be rejected are: unrealistically small observation duration where the scientific goal will not be achieved, and survey-type proposals of the kind "*I want the data of all observations with sources from the supplied list/or from all observations with sources of type 'x' in the FOV, but do not request any extra time*".

Each requested observation for each target of a proposal must be entered into the proposal using PGT, otherwise it is not considered by the TAC for evaluation. Hence, targets listed in the scientific justification but not entered in PGT, are not considered by the TAC. The Principle Investigator can request a PGT compatible version of their proposal submitted in response to an earlier AO via the helpdesk. This is very useful in case of long lists with targets and saves re-entering all the observation information. Instructions on downloading and using PGT and other supporting observation tools are given in §5.

4.3.2.2 Key Programme associated proposals

Proposals that are to be associated with a Key Programme (see §§ 1.6, 3.1.7, A.8 and *"AO-6 Key Programmes and Associated Observations"*) are treated somewhat differently. Association with the KP within PGT restricts the options available. This is described in the "*AO-6 Observation Tools Software User Manual*". As is the case for standard observation proposals, all targets for which data rights are claimed, must be entered into PGT, and the science justification is the primary element used by the TAC to evaluate the proposal. Only sources for which the minimum effective exposure is greater than 100 ks, can be associated to a KP. It must be demonstrated that the time accumulated during KP observations at the target's location will eventually allow the observer to meet the stated scientific objectives, and that the public archived data are not sufficient.

4.3.3 Proposal handling and Time Allocation Committee

After the deadline for an AO, ISOC will perform a technical feasibility of the submitted proposals using the Target Visibility Predictor (TVP) and the Observing Time Estimator (OTE), and forward the proposals to the TAC for scientific assessment.

Proposals are reviewed by a single, international TAC based on scientific merit and guided by a list of evaluation criteria, established during the first AO. This committee consists of three panels covering the range of scientific topics relevant to INTEGRAL:

- **Compact objects**: black holes and neutron star binaries, pulsars, isolated neutron stars and galactic jet sources.
- **Active Galactic Nuclei**: Seyferts, Blazars, quasars, but also normal galaxies, clusters of galaxies and cosmic background.
- **Nucleosynthesis and miscellaneous**: including supernovae, supernova remnants, novae, Wolf-Rayet stars, diffuse (line) emission, inter-stellar phenomena, gamma-ray bursts, gamma-ray burst sources and anything not in the two categories given above.

The TAC is advised to reject proposals for observations whose aims have been addressed or attained within the Core Programme or past AOs. Proposers should therefore carefully check any possible duplication of their observations by looking at the INTEGRAL target list available via the ISOC web page, by clicking on either 'Observing Programme' or 'Approved Target Lists'.

The TAC is advised to allocate time for an oversubscription factor of about 1.5 to increase scheduling efficiency. This means that not all accepted proposals can be scheduled within the AO. Preference will always be given to higher ranked proposals.

GRB proposals and proposals associated with the AO-6 Key Programme will be evaluated normally by the TAC. However, they only receive a final mark and will not be graded A-C, as they have no scheduling priority of their own.

The TAC is advised to accept only a limited number of proposals for Targets of Opportunity (see §3.1.3); scheduling of TOO observations reduces the overall efficiency of the mission by deviating from the long term scheduling plan.

Based on the results of the assessments, the TAC will recommend for each proposal its approval (i.e. all requested observations), partial approval (some of the requested observations, possibly with reduced observation time), or rejection. In addition, all accepted proposals are ranked with a letter grade and a mark. The recommended programme is then approved by ESA. **The decision of accepting or rejecting a proposal is final and non-negotiable**. The TAC must provide comments for each proposal, including the reasons for rejection, and these are subsequently communicated to each PI by ISOC.

Following the TAC assessment and endorsement by the ESA Science Director of the recommended observing programme, a database of approved observations and associated details is created and maintained by ISOC. This database contains General Observer, Key Programme, and Core Programme observations. A subset of these data is made available to the ISDC.

4.3.4 Scientific mission planning

This section describes the scientific mission planning including execution of observations, scheduling and re-scheduling.

During routine observations, ISOC generates and maintains detailed observing schedules based on the approved observations (from the GO, KP and CP), and delivers these schedules to MOC for uplink and execution. The ISOC scheduling takes into account: celestial viewing constraints, observation efficiency (i.e. observing versus slewing time), scientific value, and any other special requirements such as fixed-time observations. Some observations are too long to be scheduled as a single time block; ISOC must therefore schedules such observations as more than one separate exposures. Both ISOC and MOC provide details of the "live" schedules to ISDC.

Sometimes, the need to reschedule may entail important changes to the pre-planned sequence of observations/operations. Such circumstances are encountered in the case of:

- TOO trigger
- Instrument or spacecraft anomaly
- Unforeseen ground station outages.

Re-planning at MOC can be done at most once per orbit, and can only be justified in the case of a TOO trigger or an anomaly. The reaction time is typically 8 hours from the receipt of the ISOC request. Any other re-planning, related to optimization of instrument configuration, for example, is generally implemented by MOC in the revolution starting at least 8 hours after the request from ISOC.

The rescheduling of an observation is considered by ISOC only if the ISDC deems that it did not yield useful scientific results. An abnormally high background level, due to solar activity for example, is not regarded as a justification for re-scheduling. If the prime instrument is switched off, however, the observation will generally be re-scheduled if the off time amounts to more than 15% of the approved observation.

ISOC aims to schedule and execute 100% of an observation's approved time. However, ESA endorsed the TAC recommendation that any observation should be considered "complete" if at least 85% of its approved time has been executed.

4.3.5 INTEGRAL archive at ISOC

ISOC offers public access to INTEGRAL data, as does the ISDC. The ISOC Science Data Archive (ISDA) can be accessed through http://integral.esac.esa.int/isda. It uses the same browser technology as that developed for the XMM-Newton Science Archive (XSA) and ISO Data Archive (IDA). It is a highly flexible system for browsing and downloading the data and products, either at the level of observations, individual dither pointings, or so-called observation groups. Interactive tools are available for examining data from the original FITS image files and performing simple analysis tasks. ISOC continues to develop high-level data products and tools to visualize and manipulate these products.

4.4 From observation to data products: ISDC

4.4.1 Introduction

The INTEGRAL Science Data Centre, http://isdc.unige.ch/, is the link between the scientific output of the instruments on the spacecraft and the astronomical community. It is responsible for the receipt, analysis, archiving and worldwide distribution of all INTEGRAL data.

The ISDC was established in Versoix, near Geneva, Switzerland in 1996. The staff is made up of several scientists and engineers funded by an international consortium of twelve institutes with support from the European Space Agency (ESA). The ISDC works in close collaboration with the instrument teams to ensure that the software developed and maintained by these is integrated in a coherent data analysis system.

4.4.2 ISDC responsibilities, data flow and data analysis

The ISDC receives all the INTEGRAL telemetry and auxiliary data and converts these raw data to a FITS compliant format. It also monitors the scientific instruments on the spacecraft and works with the instrument teams to solve the problems that may arise. It performs a quick-look analysis of the data, and alerts the astronomical community when unexpected features and events such as gamma-ray bursts are detected.

The data flows in real-time from MOC to ISDC at a rate of ~113 kbits/s. The ISDC performs a *Quick-Look Analysis* (QLA) in *Real-Time*. The data stream is cut into a series of contiguous *Science Windows* (ScW): a 30-60 minute pointing in a dither mode or a slew of the spacecraft. Every few days, the telemetry is sent again to the ISDC on CD-ROM, in the form of *consolidated data,* where all recoverable telemetry losses (e.g. at station handover) have been corrected. These consolidated data include auxiliary files and the current observing plan, and are used in the standard scientific analysis.

The purpose of the QLA is to rapidly detect bright transient sources, large flux changes in known sources and instrument anomalies. In the case of an unusual event, the QLA results are communicated to the PI of the observation and ISOC is contacted if the event could potentially trigger a TOO or follow-up observation. Once the consolidated data have been received, the ISDC uses the *Offline Science Analysis* (OSA) software to perform a standard analysis that yields reconstructed sky images in several pre-defined energy bands, spectra and light-curves of individual sources. OSA is a pipeline of high-level software components developed primarily by the instrument teams and integrated by the ISDC. The standard analysis (SA) is generally completed within three weeks after receipt of the consolidated data. The results are stored in the INTEGRAL archive.

4.4.3 INTEGRAL data

One three-day revolution yields a telemetry volume of 2.7 GBytes. Processing of this telemetry stream yields ~17 Gbytes of uncompressed data products. These data are stored in FITS files and consist of:

- **raw data** (4.5 GBytes): reformatted data of the telemetry,
- **prepared data** (7.2 GBytes): includes additional timing information,
- **corrected data** (2.7 GByte): includes gain corrected event energy, and
- **high-level products** (2.7 GBytes): SA products including images, spectra and light curves.

They are made available to the observer in compressed format (~9 Gbytes per revolution). Raw and prepared data are stored by ScW, whereas corrected data, intermediate results of the analysis and high level data products are stored per observation, usually consisting of 10−100 ScWs. The FITS standards are used throughout and for all data products. All data delivered by the ISDC are calibrated relying on the instrument teams' expertise.

4.4.4 INTEGRAL archive at ISDC

The main archive, located at the ISDC, contains all INTEGRAL data from raw telemetry to SA products, as well as calibration and response files, auxiliary data and source catalogues. As mentioned in see §4.3.5, a second archive located at ISOC contains the same data.

All archived public data can be downloaded from the ISDC via anonymous FTP or through a web archive browser (W3Browse). FTP download is more direct but requires knowledge of the exact name or location of the data, whereas the web interface allows queries to the database by object name, coordinates, time interval and other parameters. The selected data are then extracted from the archive in tar files, compressed and prepared for retrieval. Data can also be distributed by other means as described in the next section.

4.4.5 Data distribution

A general observer can chose the means through which the data will be made available in PGT. The typical data download rate from ISDC is 1 Gbyte/hour via FTP, and generally smooth. Consequently, the use of hard media is strongly discouraged and the re-distribution of it will not be done unless the media is either defective or was lost in the mail. Distribution takes place after ISDC has received the consolidated data from ESA, processed and archived them. The whole process takes about one month from the end of the observation. Note that ISDC does not assume any responsibility for the public network capacity in regards to the transfer of large data volumes.

Observers visiting the ISDC can have a first look at the data from their observation within a few hours. The ISDC, with the permission of ESA (amalgamated observations require the approval of all PIs), gives to an observer access to the data of their observation at the ISDC. This is true for all observers wishing to look at their data before the official distribution.

4.4.6 Data rights and source naming convention

Guest observer observations are proprietary for a period of one year from receipt of the consolidated data from the ISDC.

A source naming convention for new sources detected by INTEGRAL has been established in agreement with the IAU. Source designation is IGR J*HHMMm+DDMM* (equatorial coordinates, epoch J2000) in the case of positive declination, or IGR J*HHMMm–DDMM* for negative declination. In both cases, *HHMMm* is the right ascension of the source in hours, minutes and fractions of a minute, and *DDMM* is the declination of the source in degrees and arcminutes. Coordinates must be truncated, not rounded, to comply with this convention.

4.4.7 User support and communication

The ISDC provides support in regards to the data analysis. The INTEGRAL science analysis software, together with the associated documentation and test data, can be downloaded from the

ISDC web pages at http://isdc.unige.ch/index.cgi?Soft+download. Observers are also welcome to visit the ISDC for local support and direct access to data analysis tools.

The ISDC software includes scripts to run the standard analysis and applications to visualize the data products and manage the off-line analysis. The software is available for SUN/Solaris, Mac OS X and Linux. The ISDC organizes regular INTEGRAL data analysis workshops, aiming to discuss issues relating to calibration, data analysis methods, software and results. A newsletter (http://isdc.unige.ch/Newsletter/) is used to keep the community informed and encourage communications with the ISDC. Subscription is done on the web site.

4.5 Gamma-ray bursts

Data from Gamma-Ray Bursts (GRBs) are generally treated as for a TOO (see §3.1.3). In such instances, however, three additional features are specified to facilitate follow-up observations:

- GRB position, trigger time, duration and flux estimate.
- GRB time history derived from the SPI Anti Coincidence Shield subsystem.
- Fast uplink of special OMC sub-window.

These are described in greater detail below.

4.5.1 GRB position and trigger time

INTEGRAL has no on-board GRB detection and triggering system. However, it continuously downlinks its acquired data to Earth allowing for constant, near real-time, monitoring. At the ISDC all data are automatically analysed to detect transient events. In addition, a fast analysis is performed by the INTEGRAL Burst Alert System (IBAS) with several detection algorithms running in parallel.

As soon as a GRB candidate event is detected, it must pass a screening that involves a more detailed off-line analysis. The GRB position, trigger time, flux and duration are submitted to the alert generation process and broadcasted. The rate of GRBs is about one burst per month within the IBIS and SPI FOVs. Localization accuracy is a function of the event's S/N ratio, the spacecraft attitude and stability, the angular resolution, and whether the event took place in the fully or partially coded FOV. The first alert broadcast message has rather crude information. Therefore, subsequent alert messages are sent out to subscribers with more accurate information on the position and source characteristics. In order to facilitate rapid follow-up observations (e.g. using XMM-Newton, Chandra, Swift and Suzaku), data describing the GRB peak (2–200 keV, 1 s), fluence (20–200 keV), lightcurve (20–200 keV, plot only), and duration are made available shortly after (see http://isdc.unige.ch/index.cgi?Soft+ibas for details).

Alerts with the coordinates of GRBs are distributed through internet sockets for robotic telescopes using the UDP transport protocol. The required software can be requested from the ISDC. E-mail alerts are distributed via GCN circulars. The typical uncertainty is smaller than a few arcminutes. The interactive analysis used to confirm the event and to derive the most accurate GRB position, is generally performed within a few hours after the automatic delivery of the first alert message(s).

In operating an automatic GRB alert system, users must be aware that this implies that some IBAS alerts may be spurious, i.e., unrelated to an actual GRB.

4.5.2 GRB data from the SPI anti-coincidence (veto) subsystem

INTEGRAL is well suited as the near-Earth node of the **I**nter**P**lanetary **N**etwork (IPN) providing large area detectors like SPI's **A**nti-**C**oincidence **S**hield (ACS). The ACS collects GRB data in time bins of 50 ms, time-tagged to an accuracy of 1 ms at energies above 75 keV. Thus the data of about 300 (5σ) bursts per year, located mainly perpendicular to the instruments' FOV, are used by the IPN. These time series (contained in the instrument housekeeping data) are also provided via the ISDC GRB alert system to the scientific community and thus immediately publicly available.

4.5.3 OMC window handling in case of a GRB alert

Due to the limitation of telemetry rate, it is not possible to download all OMC data. Thus it is necessary to pre-define specific OMC CCD sub-windows (covering ~1% of the total CCD area) for routine observations. It is possible that a GRB, detected by IBIS via the ISDC alert system, is in principle observable by the OMC as it is taking place in its FOV, but the pre-selected sub windows (selected prior to the observation) do not cover its position. To enable GRB monitoring by the OMC, it is necessary to promptly order a change of the sub-window such that it covers the GRB, overriding the pre-defined sub-windows for the **duration of the on-going (dither) pointing only** (i.e., ≤60 minutes), until the next set of pre-defined OMC sub-window commands associated with the following dither pointing.

In order to allow a near real-time implementation of the required new OMC window commands the required functions are split between ISDC and MOC only. In summary the ISDC software:

- identifies a GRB from IBIS near real-time science data
- identifies the GRB location in IBIS detector coordinates
- converts IBIS detector co-ordinates to OMC detector coordinates
- checks whether location is within OMC FOV
- provides necessary input to MOC, only if the previous check is positive

Upon receipt of this message, MOC

- accepts and checks (syntactical) correctness of input
- generates necessary telecommands
- uplinks necessary telecommands

This process has been successfully used in flight.

The size of the new up-linked OMC sub-window is 91 × 91 pixels. The data collected from all other pre-defined sub windows during that pointing are lost. It is estimated that the new OMC sub-window will be effective about one minute after the detection of the event (nominal case). It is noted that this mechanism has been established only to provide the described functionality for the OMC. As it violates some of the basic mission principles, including safety considerations, it cannot be applied for other cases. No other commands (especially to AOCS) are sent in response to a GRB.

5 Proposal submission procedure and tools

5.1 Proposal Generation Tool (PGT)

Proposals must be prepared and submitted electronically using the Proposal Generation Tool software. ***Other formats will NOT be accepted***.

PGT must be downloaded from the ISOC web page (http://integral.esac.esa.int/) and run locally. It is written in JAVA and requires the correct version of the JAVA run time libraries. PGT is used for the preparation, editing, printing and submission of INTEGRAL proposals. The scientific justification for the proposals must not be longer than five A4 pages and in PDF format. It is uploaded through PGT and submitted electronically together with the rest of the proposal.

Prospective proposers may wish to 're-use' their old proposals from earlier AO's, updating them as necessary for AO-6. However, PGT has been modified for AO-6 and the old proposals are no longer consistent with the new software. To support the community in this, the ISOC will, on request only, generate a copy of an old proposal in the new format (consistent with the AO-6 PGT), and send it to the proposer. A proposer should send such a request to the INTEGRAL helpdesk, quoting the Proposal ID of the relevant proposal. ***ISOC will only send a proposal back to the original PI***.

Please see Appendix A: *"Proposals – format and checklist"*, for a description of some essential points regarding submitting a proposal using PGT, or *"AO-6 Observation Tools Software User Manual"* for more details.

5.2 Observing Time Estimator (OTE)

The Observation Time Estimator is available via the ISOC web page.

The OTE is the only official way to calculate the observing times for the two main INTEGRAL instruments: IBIS and SPI. It is also used by the ISOC for the check of the technical feasibility of all observations. Observers are strongly advised to use the OTE to calculate requested observing times, since it is imperative that sufficient information is provided in the proposals to allow feasibility checks to be performed by ISOC.

5.3 Target Visibility Predictor (TVP)

The Target Visibility Predictor is available via the ISOC web page.

In principle, any point on the sky is observable by INTEGRAL. This is not, however, true for any point in time. The TVP can be used to calculate visibility for each celestial source taking into account the constraints discussed below, with the exception of the SPIBIS effect (see §5.3.3), which is only considered at the scheduling level.

5.3.1 Sun and anti-Sun viewing constraints

TVP respects the constraints on the **S**olar **A**spect **A**ngle (SAA) of the spacecraft, described in §2.2.3. As a consequence of this constraint, the sun cannot be observed at any time.

5.3.2 Earth and Moon viewing constraints

In order to ensure correct functioning of the spacecraft's star trackers (see Figure 1), co-aligned with the instruments' pointing axis, the spacecraft has to point at least 15^{o} away from the Earth and 10^{o} away from the Moon limb during standard observations. TVP takes these constraints into account.

Note that observations of the Earth have been performed in AO-3, but such observations require elaborate non-standard mission planning and execution, and hence cannot be performed as part of the routine operations.

5.3.3 Other constraints

Eclipses:
Observations are usually carried out while the spacecraft is outside the Earth's radiation belts at an altitude of at 40 000 km or more. The exact limits are occasionally adapted, as required by changes in the extent of the belts. No observations are performed within 30 minutes prior to and following an eclipse (i.e. when INTEGRAL is in the Earth shadow with respect to the Sun).

SPIBIS:

SPIBIS is an effect by which a shadow of the SPI mask is cast onto the IBIS detectors. This occurs rarely and only when a bright source, like the Crab nebula or Cygnus X-1, is positioned 30–50° off-axis and within a narrow azimuth angle range around the spacecraft's Z-axis. This effect can be avoided by excluding from the scheduling, time periods during which a bright source lies within the critical area. ISOC avoids scheduling such observations as much as possible. More details can be found in the current AO's "*IBIS Observer's Manual*".

5.4 Software updates

It is highly recommended to use the latest version of the software and AO documentation. The ISOC will try to avoid updates of these between the issue of an AO and the deadline for proposals. Users are therefore advised to sign-up to the email distribution list by sending an email to the INTEGRAL helpdesk (inthelp@sciops.esa.int), with the text "update distribution list" in the subject. This will provide information on the software and documentation provided by ISOC. Observers who have signed up during previous AOs, need not re-apply. Questions concerning the instruments, the AO and anything related to INTEGRAL, should be directed to the helpdesk.

5.5 Proposal deadline

Proposals must reach ISOC by Friday April 18, 2008 at 14.00 CET (13.00 GMT).

5.6 Ongoing modifications to the observing programme

During in-orbit operations, changes to the instrument performances may occur. In addition, the instrumental background varies with the solar cycle: at Solar minimum, the Sun's magnetic field can propagate more easily into the inner Solar System. These changes may influence the integration time required for the observations. The effects of any such changes on the instrumental performance are routinely monitored. If the expected changes in integration time or signal-to-noise ratio are significant, the observers will be notified, the TAC chairman will be consulted, and the integration times modified by ISOC. In principle, once an observation is approved, it will be carried out even if the required integration time increases, provided that it is still feasible.

Moreover, the TAC can re-classify a KP-associated observation into a standard observation and vice versa. Some changes, however, are not allowed:

- Change of source or pointing direction.
- Change from standard to fixed time observation.
- Change from standard or fixed time to TOO observation.
- Change from TOO to standard or fixed time observation.

Appendix A: Proposals - format and checklists

A.1 Introduction

The only interface for submission of proposals is the PGT software. Here, you will find some general information and rules for the inputs to PGT. More details are found in the current AO's "*Observation Tools Software User Manual*".

A.2 PGT inputs

The PGT inputs are split into several screens:

- The Main screen, where the Proposal ID can be entered.
- The Admin Details screen, where the administrative details of the PI and Co-Is need to be entered (e.g., names, addresses etc.)
- The Proposal Details screen, where general information about the proposal is given (title, abstract, category and scientific justification). The scientific justification is appended to the proposal as an attachment.
- The Observation Details screen, where information for each observation is given.

The Proposal ID is assigned by the Proposal Handling System at ISOC and sent to the observer by email upon successful reception of the first proposal submission. It is needed subsequently only for submitting an updated version of the same proposal.

A.3 Target coordinates

While ISOC does perform verifications on the validity of the source coordinates, it is nonetheless ultimately the responsibility of the proposer to make sure that the coordinates (J2000) entered into PGT for the target are correct. (PGT performs a validation of the coordinates using SIMBAD given the source name entered in the proposal; only a warning is given if the values of the coordinates do not match those returned by SIMBAD). Since changes to the source or pointing are not allowed after TAC approval (except in the case of obvious errors discovered by the proposer), observations for which target coordinates are incorrect could be lost. ***Proposals for new (unknown) TOOs or GRBs in the FOV can use coordinates (0,0) in PGT***.

A.4 Scientific justification

The scientific justification has to be written in English and should be attached to the proposal in the Proposal details panel, using the "New Attachment" button at the bottom of the page. The attached file should be in PDF format. The justification should use A4 paper size, and a maximum of 5 pages, including figures and tables. Font size must not be smaller than 10-point.

The Observation Details panel in PGT allows only a small amount of information on the source flux to be entered in the proposal. In many cases this may not be sufficient information to judge the technical feasibility of the proposal, and the proposer is advised to give details on fluxes, spectral shape, line strength, line width, etc. for his sources in the scientific justification. These details will be taken into account by ISOC when doing the technical feasibility check.

Only targets included in the PGT will be considered for approval. Observations mentioned in the scientific justification or abstract but not entered into PGT will not be considered.

A.5 Integration times and GRB observations

For all observations other than those associated with the KP, proposers must specify an integration time in PGT (this is a mandatory field in PGT and cannot be left blank). In general the integration time should be calculated using the Observing Time Estimator software (OTE), which will calculate how much time is required to achieve a given significance for a given flux. ISOC will use the same software to perform the technical feasibility checks on the proposals.

This is not the case for observations of GRBs in the FOV. The duration of these events (of the order of 100 seconds) and the possible afterglow of a few hours, are short compared to the typical duration of an INTEGRAL observation. Also these cannot be treated as standard TOO follow up observations, since no re-pointing is possible on such short time scales. Therefore, observers interested in data of GRB sources in the FOV cannot estimate their integration times using the OTE, since they are basically interested in receiving data for a period of time around the GRB event. However, OTE can still be used to estimate the minimum detectable flux in a given energy band with the SPI and IBIS instruments, thus allowing to estimate the detectability of a GRB. In such cases, proposers should specify in PGT the period of time for which they want to receive the data of the detected GRB. This can be before and after the event (the split between the time before and after the event needs to be specified in the scientific justification).

A.6 TOO and fixed time observations

For Targets of Opportunity (TOO) and Fixed Time observations, the proposer has to fill in a short justification for each observation in PGT in addition to the scientific justification for the proposal. These justifications must be entered in the appropriate window in the PGT observation details screen. For TOOs this should specify why this observation should be regarded as a TOO, and when the TOO should be triggered (flux levels, etc.). Note, however, that it is the proposer's responsibility to inform the Project Scientist that the TOO trigger has been met. (For TOOs discovered in the FOV of INTEGRAL and for which a proposal exists, the proposer will be informed that this TOO is active, after which the proposer decides whether to activate the TOO follow-up observation or not). The TOO alert form on the ISOC web site should be used only to request that a TOO be scheduled. The form can be found at the 'Target of Opportunity Alert' link on the ISOC home page, or directly via the URL:

http://integral.esac.esa.int/isoc/html/too/my_too_alert.html.

In the case of fixed time observations the proposer must specify in the scientific justification, why a fixed time observation is required, and when the fixed time observation should be performed (if this is known). This information will be used by ISOC to determine when to schedule the observation. Note that for fixed time observations, for which a time or date for the observation is already known, it is imperative that the proposers check the visibility of their sources using the Target Visibility Predictor for the dates and times they want their observation to be performed. (See §3.1.3 for a discussion on TOO observations.)

A.7 Coordinated observations with other facilities

ISOC provides support for coordinated observations with other facilities. Proposers are particularly encouraged to apply for coordinated observations with XMM-Newton (see §3.1.6).

Proposers who want their observation to be coordinated with another facility should enter it as a fixed time observation, indicating that the reason for the fixed time is that it is coordinated with another observatory, and specify its name. ISOC will try to accommodate the coordinated observation, but the proposer remains responsible for the coordination between observatories. ISOC mission planners are nonetheless, in regular contact with mission planners on other missions such as RXTE, XMM-Newton, Suzaku, Swift and Chandra. Note that since INTEGRAL observations are generally long, it may be easier for other observatories to follow the INTEGRAL scheduling (especially ground based observatories).

A.8 Association with Key Programme

For KP associated proposals, the proposer must click on the checkbox “Associate with Key Programme”. Since KP pointings and instruments configuration are pre-defined, the proposer must only specify the target(s) for which data are requested. KP association de-activates certain fields in the “Observations Details Panel” such as settings and dither pattern selection.

A.9 Checklist for the proposal

The proposal text **must** contain at least the following three items:

1. **the scientific case**
2. **the observation strategy**
3. **demonstration of the feasibility of the observations**

The proposal should be checked against the following questions:

- Is your science justification complete? Does it contain the mandatory three sections mentioned above? Do you have a special justification if requesting more than 1 Ms?
- Have you filled in the Observations Details Panel for *all* observations of *every* source?
- If your observation has any scheduling constraints, have you marked it as “fixed time”?
- If your proposal is for GRB data, have you supplied the trigger criteria and the time interval of the data you request?
- If your proposal is for KP data have you selected the button labelled “Submit as Key Programme Association”?
- If you are not using the standard 5 × 5 dither, have you justified the use of this other pattern?
- If you plan to observe a region of the sky which will be observed in the Core Programme, or has been observed in the Core or Open Time programmes, have you explained what new science will be addressed by your proposed observations?
- Can your programme only be done with INTEGRAL? Can’t it be done using archival data?
- Have you checked the latest news on the INTEGRAL page (http://integral.esac.esa.int/)?