INTEGRAL

Announcement of Opportunity for Observing Proposals (AO-1)

INTEGRAL Guaranteed Time

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I. Introduction

According to the Science Management Plan for INTEGRAL, the observing time is defined as that time during which the scientific instruments on INTEGRAL are in nominal operation, less idle time and less time necessary for slewing, uplink commands, calibration, testing and maintenance.

Scientific observing time for the observing programme during the nominal/extended mission phases, starting at the end of the initial commissioning phase of 2 months duration, is divided into the open time for the General Observer (General Programme) and the **guaranteed time** for the INTEGRAL Science Working Team (**Core Programme, CP**). The breakdown into these two programme elements is shown in Figure 1.

The observing time (**guaranteed time**) during the **Core Programme** is the return to the INTEGRAL Science Working Team (ISWT) for their contributions to the development and execution of the INTEGRAL programme. The ISWT is composed of 15 scientists, namely: 2 Co-PI’s for the spectrometer SPI; one PI and one Co-PI for the imager IBIS; one PI each for the optical monitor OMC, X-ray monitor JEM-X and INTEGRAL Science Data Centre, respectively; five Mission Scientists (three from Europe, one from Russia, one from USA); one scientist each representing the participating partners Russia and USA; and the ESA Project Scientist[1]. It is a task of the ISWT to define the Core Programme in full detail.

1. The elements of the Core Programme

The Core Programme consists of three elements which will be further discussed below:

- Frequent scans of the Galactic plane (Galactic Plane Scans, GPS)
- A deep exposure of the Galactic central radian (Galactic Central Radian Deep Exposure, GCDE)
- Pointed observations of selected sources.

This document describes in detail, for each CP element,

- the scientific rationale,
- the detailed observing strategy, and,
- exposure times and estimated sensitivities.

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2. Time allocation for Core Programme elements

Given the characteristics of the INTEGRAL operational orbit, described in the *INTEGRAL Manual* in detail, and using the annual share of the Core Programme (CP) time (Figure 1), the allocation of observing time as shown in Table 1 has been derived for the three elements of the Core Programme for the first year of the mission. The allocation has been driven by the highest scientific priority which has been given to GPS and GCDE. Note that Table 1 takes the simple assumption into account that science observations will only be performed above an altitude of 40,000 km.

The ISWT will, as determined by significance of unforeseen scientific events, maintain some (limited) flexibility in the time allocation for the CP elements throughout the year (see below for details).

Table 1: Core Programme time allocation for the first year of the nominal mission

Total observing time per year (10^6 s)	**Total CP (10^6 s) [%]**	**GCDE (10^6 s)**	**GPS (10^6 s)**	**Pointed observations (10^6 s)**
26.6	9.32 [35%]	4.30	2.30	2.72

It has to be noted that in-flight calibrations during the nominal mission phase, i.e. after the commissioning phase, may occur (see *INTEGRAL Manual*). In line with the definition of observing time (see above), exposure time for in-flight calibration will lead to some reduction in the Core Programme time (Table 1) and General Programme (open) time. The total amount of that required time is under evaluation.

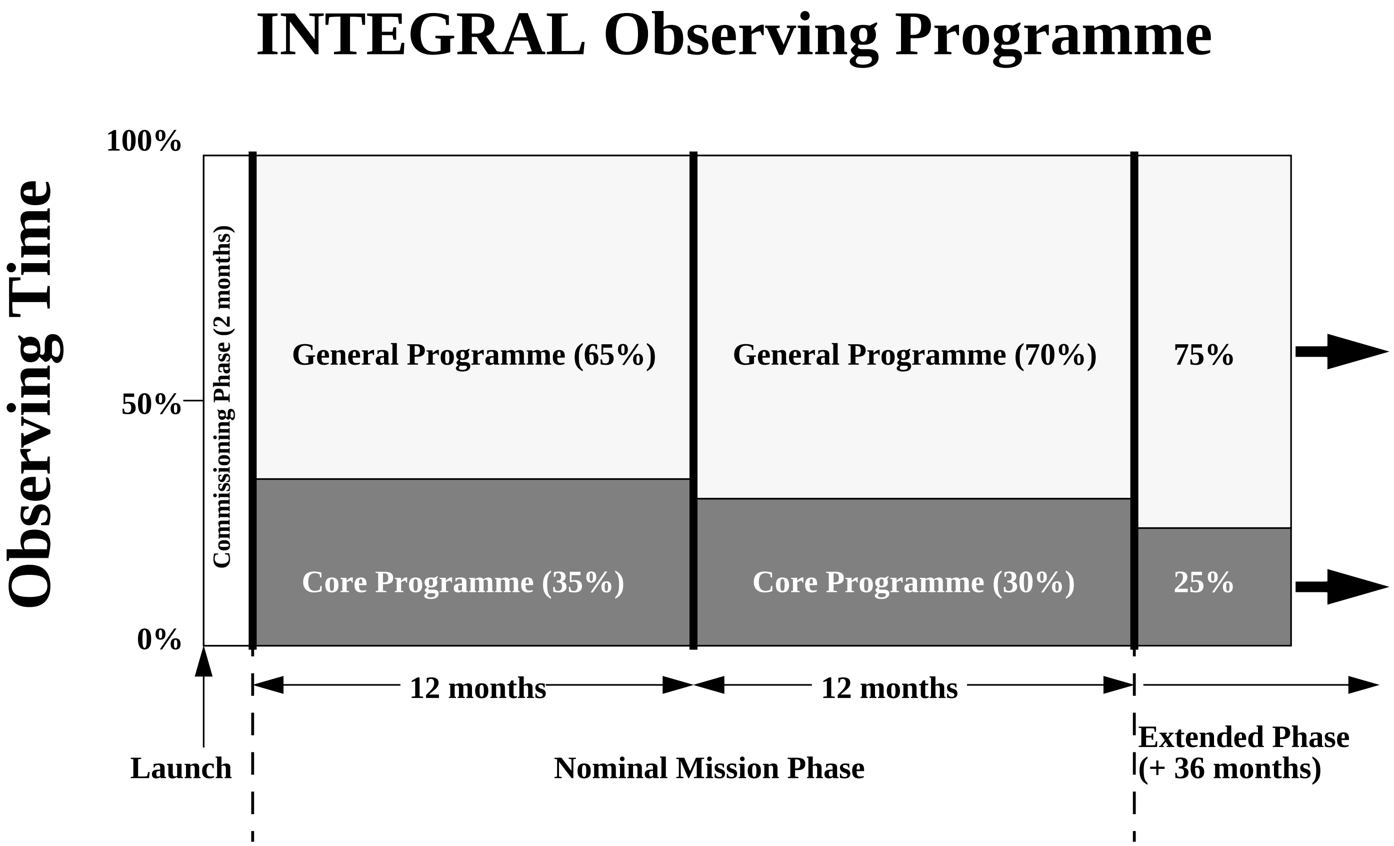

Figure 1. Breakdown of INTEGRAL observing time

II. The Galactic Plane Scans (GPS)

1. Scientific rationale

The scanning of the Galactic plane will be mainly done for two reasons: the most important one is to provide frequent monitoring of the plane in order to detect transient sources because the gamma-ray sky in the INTEGRAL energy range is dominated by the extreme variability of many sources. The scans would find sources in high state (outburst) which warrant possible scientifically important follow-up observations (Target of Opportunity [TOO] observations). The second reason is to build up time resolved maps of the Galactic plane in continuum and diffuse line emission such as ^{26}Al and 511 keV with modest exposure. As the scanning is provided by the entire spacecraft, all four instruments onboard INTEGRAL will simultaneously collect scientific data during the GPS (as well as during the other elements of the Core Programme).

CGRO and SIGMA have been detecting Galactic transient sources of several different categories/groups which include X-ray binaries (e.g. X-ray novae, Be binary pulsars) and in particular superluminal sources (GRS 1915+105 and GRO J1655-40). The occurrence rate for events that INTEGRAL can observe is about 2 events/year for each of these classes, taking pointing constraints due to the fixed solar arrays into account. The important time scales for the transient outbursts vary significantly from class to class and from event to event, but a typical duration of an event is 1 - 2 weeks and a typical variability time scale is of the order of 1 day. This implies that a weekly scan of the Galactic plane will allow the transients to be found. Obviously more frequent scanning at lower sensitivity that would find fast transients had to be traded-off against less frequent scanning at higher sensitivity that would find weak events.

Other topics of scientific interest include: study of previously unknown persistent sources; comparison of spectral and temporal characteristics (neutron star and black hole candidates); gamma-ray properties of pulsars.

2. Detailed observing strategy

The baseline set of parameters describing the GPS scans are summarised in Table 2 below. They are the result of an optimization process taking spacecraft and ground segment elements, instrument characteristics and scientific objectives into account. Basically the scans will be performed once a week by executing a “slew and stare” manoeuvre of the spacecraft across the visible (accessible) part of the Galactic plane with an extent in latitude up to +/-10^{o}. The angular distance between two “staring points” along the scan path is 6^{o}, the extremes in latitude of the pointings are at b = +/- 6.45^{o}. The scans will be performed in a sawtooth pattern with inclination of 21^{o} with respect to the Galactic plane, each subsequent scan being shifted by 27.5^{o} in galactic longitude. A schematic view of two consecutive scans is shown in Figure 2. The sum of all GPS scans during a year provides a set of grid points (“dither pattern”) which facilitates the imaging with SPI. The accessible part of the Galactic plane depends on viewing constraints, including the solar aspect angle, and on the season of the year. Figure 3 shows the Galactic plane visibility during the first year. These visibility constraints are valid for a launch in April 2002.

Table 2: Baseline parameters of GPS scans, year 1 of the nominal mission

Parameter	Value	Notes
Solar Aspect Angle	+/- 40 deg	outside eclipse seasons
Solar Aspect Angle	+/- 30 deg	during eclipse seasons
Slew mode	open	
Inclination wrt gal. plane	21 deg	
Max latitude	$\|b\| = 6.45$ deg	
Step size along path	6.0 deg	12 points per saw-tooth period (Figure 2)
Duration of 6^{o} slew	300 s	Based on s/c specification
Time for initial slew prior to each GPS scan	720 s	Assumes a 30 deg slew (150 deg/hr) prior to each GPS scan. For all scans within one year (see Figure 3) 7.49×10^{4} s are needed.
Exposure per point	1050 s	Must be > 480 s for attitude reconstruction
Exposure time/slew time	3.5	
Total (slew + exposure) per point	1350 s	
Phase shift for subsequent scans in longitude	27.5 deg	
Scan frequency	1 per week	Preferably on Mondays due to ISOC/planning constraints and TOO detection/implementation constraints

The instrument modes for GPS exposures are nominal, i.e.: SPI (photon-by-photon), IBIS (photon-by-photon [ISGRI], histogram [PICSIT]), JEM-X (full imaging), OMC (normal).

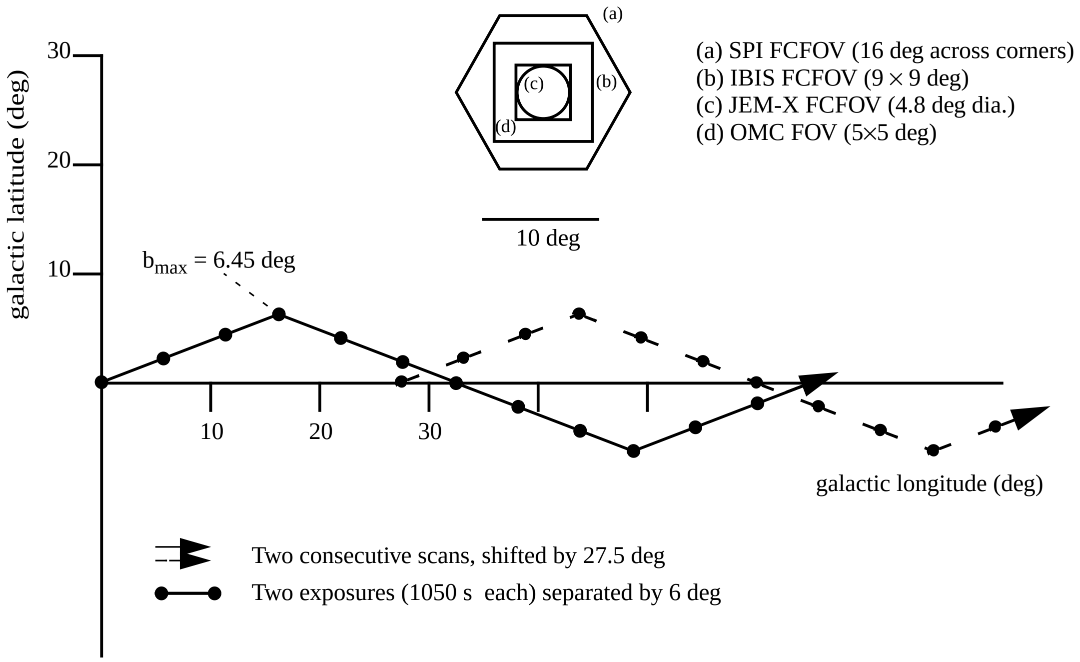

Figure 2. Schematic view of two consecutive GPS scans

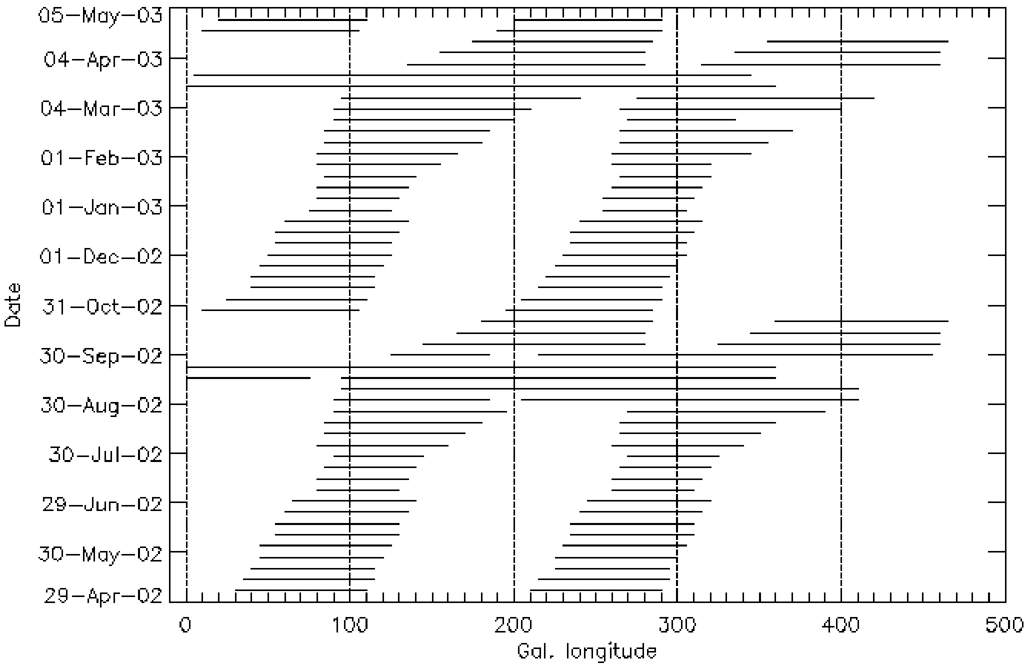

Figure 3. Visibility of the Galactic Plane, year 1 (launch 22 April 2002). The extent of the visible part of the Galactic plane (with +/- 10^o in galactic latitude) is shown by the solid lines.

3. Exposure time and sensitivities

The IBIS continuum sensitivity for a 1050 s exposure is shown in Figure 4. This will correspond to a 3σ sensitivity of ~1.5 $\times 10^{-5}$ photons cm^{-2} s^{-1} keV^{-1} @ 100 keV and ~1.9 $\times$ 10^{-5} photons cm^{-2} s^{-1} keV^{-1} @ 1 MeV. For SPI a 1050 s exposure would result in a 3σ sensitivity of ~ 4.6 $\times$ 10^{-6} photons cm^{-2} s^{-1} keV^{-1} @ 1 MeV (continuum) and 1.6 $\times$ 10^{-4} photons cm^{-2} s^{-1} @ 1 MeV (narrow lines). Table 3 shows that the typical 3σ sensitivity (in units of photons cm^{-2} s^{-1} keV^{-1}) which can be obtained for one "staring" point (see below) during a scan is 8.8 $\times$ 10^{-6} @ 100 keV (IBIS), 2.5 $\times$ 10^{-6} @ 1 MeV (SPI) and 4.0 $\times$ 10^{-4} @ 6 keV (JEM-X). This will allow detection of transient sources throughout the Galaxy.

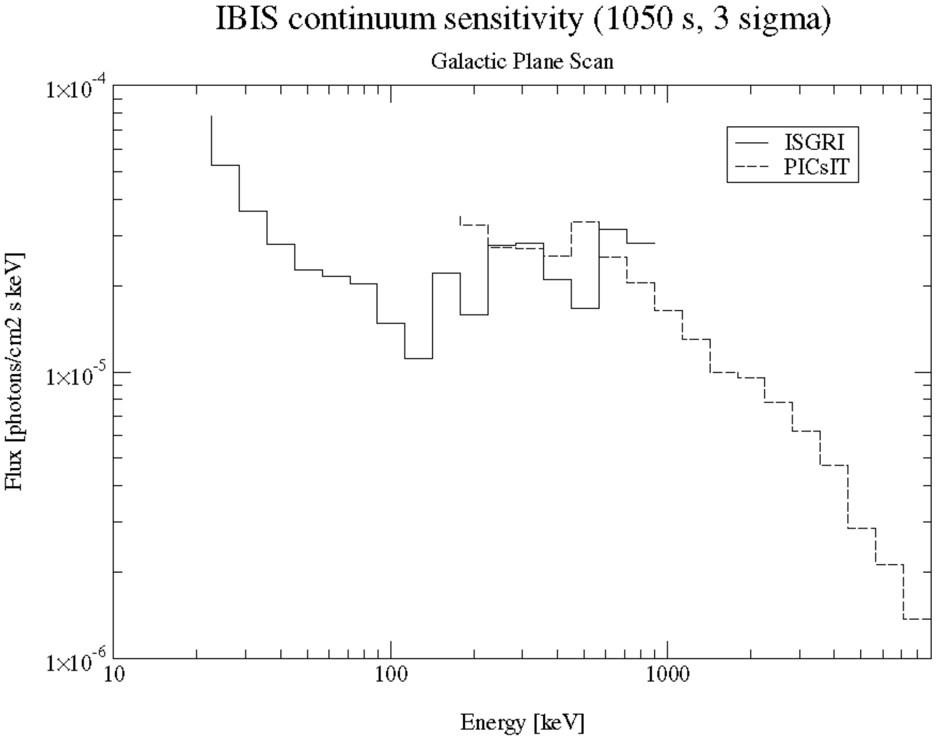

Figure 4. IBIS continuum sensitivity during a GPS exposure (1050 s)

For IBIS and SPI the sensitivity will further improve by a "FOV factor ϕ": due to the large FOV of SPI (fully coded field of view, FCFOV = 16^o across) and IBIS (FCFOV = $9^o \times 9^o$), a single "staring" point on a GPS scan will receive more than the nominal 1050 s exposure per pointing. Because this exposure point is still located within the partially coded field-of-view (PCFOV, coverage to zero response), additional exposure will be collected as the spacecraft (i.e. the co-aligned instruments) is pointing at neighbouring positions of this single exposure point (see Figure 2). This leads to the definition of a "FOV factor" which multiplies the single exposure per point by taking the full FCFOV and PCFOV coverage to zero response into account. This FOV factor (ϕ = 3.1 for IBIS, 3.3 for SPI and 1.0 for the monitors) and other exposure related parameters are listed in Table 3 using the baseline set of parameters for the GPS (Table 2) as input.

It has to be noted that Table 3 lists average values only for the GP visibility (~ length of a GPS scan), and for the number of steps and the scanning duration of one GPS scan. Based on seasonal effects (Figure 3) these numbers can vary significantly throughout the year: for example during the nominal mission the GP visibility (~ scan length) and the duration of one GPS scan will vary between minimum values of ~100^o for length, and duration of 6.8 h (January, July), and maximum values of ~350^o and 23.6 h (March, September), respectively.

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Table 3: Baseline GPS parameters related to exposure and sensitivity (year 1 of nominal mission)

Parameter	Value	Notes
FOV factor IBIS	3.1	See text
FOV factor SPI	3.3	See text
FOV factor JEM-X	1.0	See text
FOV factor OMC	1.0	-
Galactic Plane visibility	178.4 deg	Annual average for length of scan
Number of steps	32	Number of steps for scan of average length
Total time for scan	12.3 h	Duration for scan of average length
FOV exposure/point (IBIS)	3255 s	Continuum sensitivity[a]: 8.8×10^{-6} @ 100 keV
FOV exposure/point (SPI)	3465 s	Continuum sensitivity[a]: 2.5×10^{-6} @ 1 MeV
FOV exposure/point (JEM-X)	1050 s	Continuum sensitivity[a]: 4.0×10^{-4} @ 6 keV
FOV exposure/point (OMC)	1050 s	-
FOV exposure/point/year (IBIS)	8.3×10^4 s	Total exposure per point per year taking FCFOV and PCFOV (see FOV factor) into account
FOV exposure/point/year (SPI)	8.9×10^4 s	“ - ”
FOV exposure/point/year (JEM-X)	2.7×10^4 s	“ - ”
FOV exposure/point/year (OMC)	2.7×10^4 s	“ - ”

a.in units of photons cm^{-2} s^{-1} keV^{-1}

III. The Galactic Central Radian Deep Exposure (GCDE)

1. Scientific rationale

A deep survey of the central Galactic radian is driven by the following objectives: mapping the line emission from nucleosynthesis radioisotopes (e.g. ^{26}Al, ^{44}Ti, 511 keV), mapping continuum emission of the Galactic ridge and performing deep imaging and spectroscopic studies of the central region of the Galaxy. Several interesting emission regions in or near the Galactic plane have been identified using CGRO OSSE and COMPTEL: these include the ^{26}Al (7×10^5 years half life) mapping of the nucleosynthesis sites over the past million years in the Galaxy (Diehl et al., 1995, A&A 298, 445), and the ^{44}Ti emission (half life ~ 60 year) which has been detected by COMPTEL from the Cas A SNR (Iyudin et al., 1994, A&A 284, L1). OSSE mapping of the positron - electron annihilation radiation at 511 keV shows a central bulge, emission in the Galactic plane and an enhancement of extension of emission at positive latitudes above the Galactic centre (Purcell et al., 1997, ApJ 491, 725). Other isotopes such as ^{60}Fe produce lines which are thought to be detectable by INTEGRAL. The origin of the clumpy structure of the COMPTEL observed ^{26}Al maps and the ^{44}Ti emission from hidden supernovae are key targets of INTEGRAL research. The INTEGRAL deep exposure will also study the continuum gamma-ray and hard X-ray emission from the Galactic plane. This “galactic ridge” is concentrated in a narrow band with a latitude extent of ~ 5^{o} and a longitude extent of +/- 40^{o} (Gehrels & Tueller, 1993, ApJ 407, 597; Strong et al., 1999, Proceedings 3rd INTEGRAL workshop, Ap.Lett.& Comm. 39, 221; Valinia & Marshall, 1998, ApJ 505, 134). The exact distribution and spectrum of the ridge emission is not well known. The origin is thought to be Bremsstrahlung from cosmic ray electrons, but this is also not fully established. INTEGRAL will be able to map the emission with high sensitivity and high angular resolution. This should allow the removal of the point-source origin of the emission so that the spectrum can be determined with high confidence.

The GCDE will resolve isolated point sources with arcmin location accuracy and provide source spectra with high energy resolution. At least 90 sources known as X- and gamma-ray emitters are contained in the region at ~ 10 keV and BeppoSAX, SIGMA and other earlier experiments have found this region to be filled with a number of highly variable and transient sources (Vargas et al., 1997, ESA SP-382; 129, Ubertini P., et al., 1997, Proc 4th CGRO Symposium, AIP 410, 1527). Many are thought to be compact objects in binary systems undergoing dynamic accretion. However, even for some of the brightest sources in the region (1E 1740.7-2942, GRS 1758-258) the detailed nature of the systems is not known. INTEGRAL will study the faintest sources with high angular resolution allowing multi-source monitoring within its wide field of view during single pointings. Also interesting will be searches for gamma-ray emission from SgrA* at the Centre of the Galaxy (Sunyaev et al., 1993, ApJ 407, 606).

Other topics of scientific interest include: spectral studies of emission lines, new and persistent point sources, the central annihilator.

2. Detailed observing strategy

The central radian of the Galaxy will be observed using a pattern of 4 rectangular pointing grids symmetric around the Galactic Centre with a pitch of 2.4^o (see Figure 5).

- Grid 1: 17 × 26 points (442 points), l = +/- 30 deg, b = +/- 19.2 deg
- Grid 2: 8 × 25 points (200 points), l = +/- 29.8 deg, b = +/- 8.4 deg
- Grid 3: 8 × 26 points (208 points), l = +/- 30.0 deg, b = +/- 8.4 deg
- Grid 4: 9 × 25 points (225 points), l = +/- 28.8 deg, b = +/- 9.6 deg

This pattern is chosen to minimise SPI imaging artefacts and to optimize the IBIS sensitivity towards the Galactic plane. Within $|b| < 10$ deg the grids are shifted relative to each other by 1.2 deg (1/2 pitch). By using 4 grids the exposure ratio of the areas within $|b| < 10$ deg and $|b| > 10$ deg becomes 4:1. Slew time between points is conservatively assumed to be ~ 200 s using the specification value for a 6 deg open loop slew (300 s). The nominal exposure per point is 30 minutes.

The total duration of one cycle (one pattern of 4 grids including slews) is estimated to 2.15×10^6 s. Within the total time allocation for the GCDE (Table 1) one cycle will be performed twice per year. Due to visibility constraints, the entire pattern never can be scanned at once, but ISOC will schedule a series of subscans (rasters).

The instrument modes for GCDE exposures are nominal, i.e.: SPI (photon-by-photon), IBIS (photon-by-photon [ISGRI], histogram [PICSIT]), JEM-X (full imaging), OMC (normal).

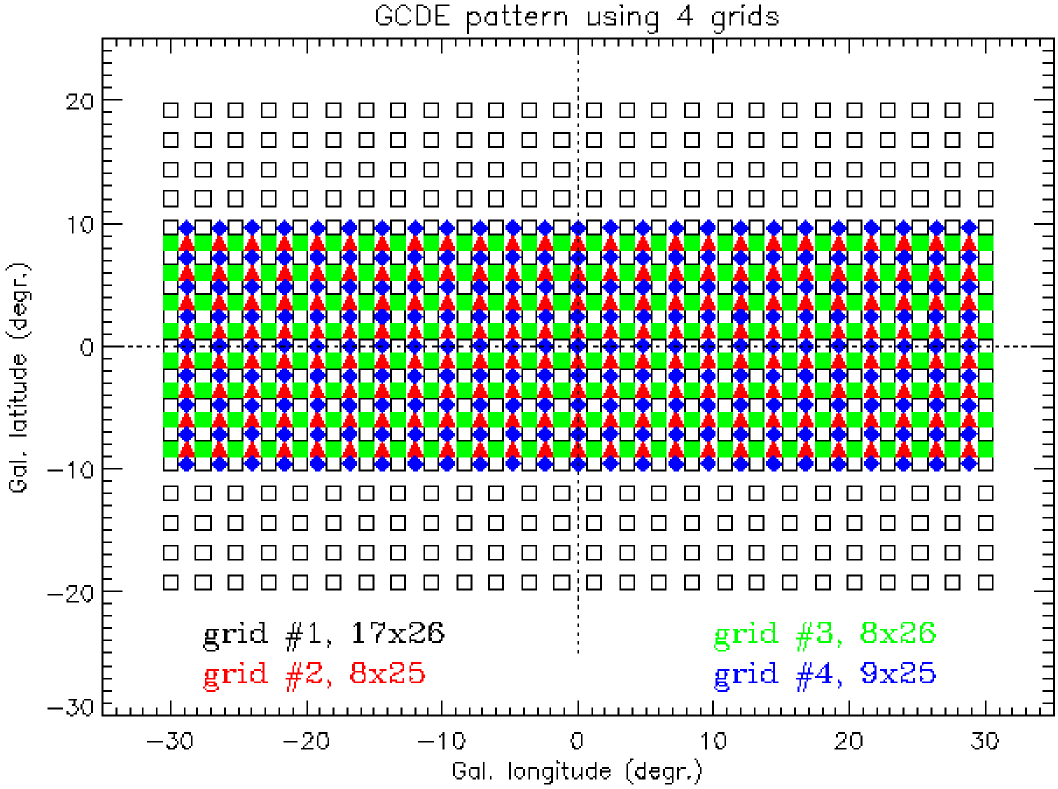

Figure 5. GCDE pattern using 4 grids.
(grid 1: ❑ grid 2: ▲ grid 3: ■ grid 4: ◆)

3. Exposure time and sensitivities

The area of size Δl = +/- 30^{o} and Δb = +/- 20^{o} centred on (l, b) = (0^{o}, 0^{o}) will receive a net exposure of ~4.0×10^{6} s which will give SPI a 3σ sensitivity of ~ 3.5×10^{-6} photons cm^{-2} s^{-1} for narrow lines in the 100 keV - 2 MeV region, sufficient for mapping and for detailed line shape studies at 1809 keV of the bright ^{26}Al “hot spots” (Gehrels & Chen, 1996, A&AS 120, 331) with typical line fluxes of ~ 3×10^{-5} photons cm^{-2} s^{-1} as detected by COMPTEL.

The continuum sensitivities (3σ) in the 100 keV to 1 MeV range will be 1×10^{-6} to 8×10^{-8} photons cm^{-2} s^{-1} keV^{-1} (SPI) and (2.5 to 3) $\times 10^{-7}$ photons cm^{-2} s^{-1} keV^{-1} (IBIS) while JEM-X will achieve ~ 3.5×10^{-6} photons cm^{-2} s^{-1} keV^{-1} in the 3 to 30 keV range.

IV. Pointed observations of selected sources

1. Scientific rationale

1.1 Introduction

Remaining Core Programme observing time not spent on GPS and GCDE will be devoted to dedicated pointings on individual sources. A significant fraction of that observation time will be set aside to be able to perform scientifically important follow-up observations on TOOs which have been detected during the GPS and GCDE or where the trigger has been observed by other observatories.

The greatest advantage of INTEGRAL, as compared to other high energy missions, is its high spectral resolution and relatively high sensitivity at energies above 100 keV. The satellite and ground segment response time to a TOO call is about 20 to 36 hours on average (see *INTEGRAL Manual*). The strongest motivation for INTEGRAL to respond to a TOO call is thus the potential detection of transient high energy emission features, such as the positron annihilation line at 511 keV, its scattering feature at 170 keV, the Li^7 deexcitation line at 480 keV, or the MeV bump, etc. It is worth noting that transient emission features around 500 keV has sofar only been detected by HEAO-1 and SIGMA, and the only simultaneous observation of OSSE and SIGMA failed to produce positive confirmations of the emission feature. This makes the INTEGRAL observations more critical.

The second most important objective for an INTEGRAL TOO to achieve is to measure the high energy continuum evolution of transient high energy events, such as a blazar flare or a X-ray nova outburst. The evolution of the high energy cutoff or spectral break as a function of time may provide critical information to our understanding of the emission mechanism and the system parameters. Historically, the above mentioned spectral features were seen only rarely and for very short periods of time ranging from a few hours to a day or so. The sources that showed these features were either transients whose outburst onset is totally unpredictable (such as X-ray nova Muscae 1991) or highly variable source (such as Cyg X-1 and 1E1740.7-2942). More importantly, the occurrence time of the desired spectral features is always unpredictable.

If the objective of a TOO is to observe the high energy continuum, several pointings for each flare or outburst are required to achieve a meaningful science return since the spectral evolution, instead of simply the spectral shape, is the main objective here. Separation between the exposures depends on the time scale of the event. A TOO monitoring of the continuum will always produce positive results unless the source has a very soft spectrum. Since there is no sure way to predict when transient spectral features may appear, the best strategy is to always point on the source as soon as possible and observe it as long (or as frequently) as possible.

Important TOO observations, triggered mostly by observations outside INTEGRAL (e.g. optical ground based telescopes) include Supernovae and Novae. The response time and exposure required to perform observations after the initial trigger depends on the source (model) and is briefly described below.

The pointed observations will be targeted at sources from three different categories:

- unknown transient sources (Section 1.2 and Section 2.),
- known transient sources (Section 1.2 and Section 2.), and
- persistent source - the Vela region (Section 3. and Section 4.3).

For year 1 the following split of CP guaranteed observing time (total for year 1 = 2.72×10^6 s, see Table 1) has been allocated: 1.7×10^6 s for unknown and known transient sources, 1.0×10^6 s for the persistent source observation (see below for details).

1.2 Strategy for selection of unknown and known transient sources

These events can be triggered from INTEGRAL detections of “high state” during GPS and/or GCDE observations or from observations external to INTEGRAL (e.g. ground-based optical telescopes) and are considered as TOO follow-up observations.

The following strategy will be applied: the allocation of 1.7×10^6 s for year one shall be used for **either** the following unknown transient sources of the following type:

- local group SN II
- SN Ia
- classical novae
- previously unknown X-/γ-transients

and/or the known transient sources

- GRS 1915+105
- GROJ 1655-40
- 1E 1740.7-2942
- Cyg X-1
- Cyg X-3
- GX 339-4
- Mrk 501

whatever TOO event comes first. Trigger criteria (see Section 4.1 and Section 4.2) have been defined so that these events listed above become scientifically an exceptionally unique - and for INTEGRAL important - target.

The reader is also referred to the TOO rules and guidelines (*INTEGRAL Manual*) and data rights concerning TOOs as described in AO document (annexe) on *INTEGRAL Science Data Rights.*

It is understood that some flexibility should be kept by the ISWT in case a **major** (“once in a lifetime”) **TOO event** (e.g. close-by SN) would occur and no or insufficient CP time for follow up observations would be available anymore because the ceiling has been already reached. In this case the ISWT could review the priority assigned for GCDE and GPS and, if available, probably re-assign remaining time from these CP elements. This would be an exception to the routine case where the execution of TOO follow-up observations will be decided by the Project Scientist.

In case **none** of the TOO events as described above take place during the first year of the mission, the allocated time will be spent on observations of the persistent source.

Trigger criteria for these sources are described in Section 4.

2. Scientific rationale for unknown and known transient sources

2.1 Unknown X-ray novae

X-ray novae outbursts (soft X-ray transients) provide the best opportunity for studying stellar-sized accreting black holes over a large dynamic energy range (> 3 orders of magnitude) in an optimal time frame of a few weeks to several months. The precise shape of the high energy continuum spectrum, the potential line emission near 0.5 MeV and the rarely seen high energy tail above 1 MeV are among the most rewarding contributions that INTEGRAL is uniquely suited for, thereby increasing our understanding of the perplexing black hole accretion phenomenon.

X-ray novae are undoubtedly one of the most important scientific targets for INTEGRAL, as thus they deserve a large fraction of core programme time. On the one side, they are bright sources for which a high quality spectrum can easily be produced. On the other side, during their outburst they pass through very different mass accretion rates in a timescale of 100 - 200 days. It is therefore mandatory to observe the outburst at different moments in order to produce a high quality spectrum for every spectral state of the source.

2.2 Supernovae (SN Ia and local group SN II)

A long standing goal of gamma-ray astronomy has been the detection of radioactive ^{56}Ni and ^{56}Co from supernovae. So far, the ^{56}Co-lines have been (marginally) detected only from one single type Ia SN (SN 1991T by COMPTEL). But the ^{56}Co-lines from the type II SN 1987a in the Large Magellanic Cloud have been extensively studied in the pre-CGRO era. ^{57}Co lines have also been detected by OSSE from this exceptionally nearby supernova.

The chance that a supernova of type Ia occurs with detectable gamma-ray line emission from the $^{56}\mathrm{Ni} \rightarrow {}^{56}\mathrm{Co} \rightarrow {}^{56}\mathrm{Fe}$ decay chain in the INTEGRAL life-time is promising. It will depend on the line broadening up to which distance a type Ia supernova can still be detected by SPI. If an expansion velocity of 10,000 km/s is assumed, the SPI sensitivity limit for detecting the 847 keV ^{56}Co-line is about 3×10^{-5} photons cm^{-2} s^{-1}. For a ^{56}Ni-yield of a 1 M_o supernova, this results in a detectability up to a distance of 15.5 Mpc. Within this distance, one type Ia supernova can be expected every two or three years (Gehrels et al., ApJ 322, 215, 1987).

The chance to detect gamma-ray line emission from a nearby type II supernova is much smaller, because of the lower ^{56}Ni-yield and the long obscuration time of type II supernovae to gamma-rays.

2.3 Superluminal jet sources

Highly relativistic radio jets have been seen from several galactic sources. The galactic jet sources appear very much like scaled down versions of extragalactic radio sources. The time scales for variability are smaller by factors of 10^6 for the galactic sources. These sources are at times very bright in the hard X-rays and have exhibited an impressive richness in temporal and spectral features, making them prime targets for INTEGRAL.

2.4 Classical Novae

Some radioactive elements being synthesized during nova explosions have yet to be detected through gamma-ray line emissions. Short lived beta unstable nuclei may be detected via the 511 keV annihilation emission. Today's most interesting gamma-ray lines are 1275 keV (^{22}Na, $t_{1/2}$ = 3.8 y) and 478 keV ($^{7}Be \rightarrow {}^{7}Li$, $t_{1/2}$ = 53 d) (Hernanz et al. 1996, ApJ 465, L27; Hernanz et al. 1999, Proc. 3rd INTEGRAL workshop, Ap.L. & Comm. Vol. 38, 407).

1275 keV: Recent results on two near novae (Nova Her 1991, Nova Cyg 1992) as observed by CGRO established 2σ upper limits of ~ (2 to 3) × 10^{-5} photons cm^{-2} s^{-1}. SPI should be able to achieve a positive detection on similar events.

478 keV: Assuming an ejected mass of 10^{-5} M_o, SPI should detect 478 keV emission for close (~ 500 pc) novae just after outburst. INTEGRAL should provide evidence whether C-O novae do produce ^{7}Li, which is under-abundant in standard big bang nucleosynthesis as compared to solar abundance by more than an order of magnitude.

2.5 Galactic transient events

Transient features

Bright, transient features have been reported from 1E1740.7-2942, Nova Muscae and Cyg X-1. In particular, for 1E 1740.7-2942 or the Great Annihilator, the 3 reported SIGMA events (@ 511 keV) lasted for 1 d, 1.2 d and 18 d. A BATSE all sky search between 300-550 keV to provide evidence for pair plasma models of black hole radiation, has not shown any evidence for such features from any point in the sky with durations between 0.5 to 3 days. The 3σ upper limits are well below the fluxes of the 2 most significant events detected by SIGMA (1E 1740.7-2942 and Nova Muscae). The SIGMA results are still debatable since the electron-positron annihilation line was not observed by OSSE.

The detection of transient broad line features with INTEGRAL while surveying the Galactic Plane and performing the GCDE will provide localized emission with precision better than 1 arcminute.

Recent results from OSSE have shown the distributions of the 511 keV diffuse emission, close to the Galactic Centre and along the Galactic Plane, and the associated positronium continuum (Milne et. al. 2000, 5th CGRO Symp., AIP 510, 21). INTEGRAL will be able to accurately map the annihilation component and the high energy positronium continuum with high angular (IBIS) and high spectral (SPI) resolution and disentangle the (suggested) transient point source contribution from 1E 1740, detected by SIGMA.

Diagnostics of spectral states

All transient black hole X-ray binaries (BHXB) spend most of their time in a quiescent/off state with a very low X-ray flux.

The presence or absence of a soft black body component at about 1 keV and the luminosity and spectral slope of emission at harder energies are invoked to distinguish the 5 distinct X-ray spectral states of BHXB. Some persistent black hole candidates (BHC) are always observed in the same spectral state (e.g. 1E 1740.7-2942 & GRS 1758-25) while the majority of the observed BHXB exhibit long term spectral variability. The most dramatic behavior is observed in soft X-ray transients (SXRT) that have been often observed in all 5 spectral states (e.g. Nova Muscae, GX 339-4) while most exhibit 2 or 3 spectral states (e.g. Cyg X-1 that routinely switches between low and high with a series of intermediate states). When data are restricted to a relatively narrow energy band, different spectral transitions may look rather similar.

Some transient BHXB (e.g. GRO 1719-24) exhibit separate flare events after declining from outburst. These secondary activities have light curves opposite to what is typically observed in X-ray novae. The spectral behavior during these flares is rather uncertain and data collected so far have not been good enough to constrain the presence of a Compton reflection component.

BATSE and OSSE data of BXHB obtained during the low luminosity power law state and during the high luminosity breaking state are not conclusive because of contamination from the bright diffuse galactic continuum emission and nearby point sources. Higher energy data from COMPTEL on Cyg X-1, though showing evidence of a very high energy tail, can not exclude contributions of other sources to the non-thermal process.

2.6 AGN/Blazars in outburst

Blazars are extreme examples of active nuclei, characterized by high polarization at optical wavelengths and extreme variability at all energies (factor 10 in optical; factor 30 in X-rays; factor 100 at GeV energies). Currently most models invoke relativistic jets, with synchrotron emission at lower energies and Inverse Compton at high energies. However in different objects the relative contributions of the synchrotron and Inverse Compton components to the total luminosity seem to be different. This is critical to test the different models (electrons versus protons versus muons: internal versus external seed photons; jet orientations and bulk Lorentz factors; total energetics). In particular the region between hard X-rays (10 keV) and EGRET energies is unclear due to relatively few data so far, which is unfortunate since such data are essential to differentiate between the models. Observations of the continuum energies between tens of keV and MeV with INTEGRAL are essential. Of particular interest is the behavior in outburst since tracking of the different spectral components with respect to each other yields a powerful probe of the physics in the emission region.

3. Scientific rationale for Vela region (persistent source observation)

The Vela region is a showcase for Galactic sources active in the INTEGRAL spectral domain. Almost all kinds of extreme sources – those where the largest energy transfers occur, such as massive stars, historical supernovae (SNe), young supernova remnants (SNRs), spin powered pulsars, accreting collapsed stars – are represented there with at least one specimen in each category known (or expected) to radiate in the hard X-ray and soft gamma-ray band. As detailed below for a selection of sources that can be fruitfully scrutinized during one single INTEGRAL pointing, this observation, whose specific significance relies above all on the closeness of many of the target sources, will provide an unprecedented set of information on the latest stages of massive star evolution. Observation of the Vela region would result in data on:

γ^2 Vel, the closest Wolf-Rayet star. Analysis of the Galactic 1.8 MeV emission from radioactive decay of ^{26}Al favour Wolf-Rayet (WR) stars as the dominant candidate source of Galactic ^{26}Al. Given the small distance of γ^2 Vel (~ 260 pc), the non-detection of 1.8 MeV emission by COMPTEL raises an unanswerable question, even in the context of the binary nature or γ^2 Vel. By testing the 1.8 MeV emission from γ^2Vel down to significantly lower flux values, the INTEGRAL survey should provide stronger constraints on the ability of binary WR stars to produce and release large amounts of ^{26}Al.

GRO J0852-46, the closest historical SN. The identification of this COMPTEL source of ^{44}Ti line emission with a nearby (~ 200 pc) and young (~ 680 y) SNR is supported by the coinciding morphology of the X-ray and radio source. The ^{44}Ti decay chain produces at equal rates lines at 68 keV, 78 keV and 1.156 MeV so that both of INTEGRAL's main instruments will provide unique pieces of information on this SN thought to result from a core-collapse event. With IBIS: an accurate location – firm identification – and a constrain on its morphology – inner SN physics. With SPI: the line profile – SN expansion velocity – and an estimate via imaging and spectroscopic (line profile) arguments of the fraction of the 1.8 MeV emission that actually relates to the ^{44}Ti line. This offers a way to test the core collapse SN models since the explosive yields of ^{44}Ti and ^{26}Al are related.

PSR B0833-45, a nearby and recent spin powered pulsar. The multi-component nature and the spectral behaviour of its pulsed emission will be monitored over the whole INTEGRAL spectral domain (including the X-ray band to be covered with JEM-X), with special attention around 100 keV, because a break at the local cyclotron energy is predicted by the polar cap cascade model.

Vela SNR, a nearby and recent SNR. The INTEGRAL survey of this nearby (~ 250 pc) and recent (~ 10^4 y) SNR has a twofold goal: (i) to estimate via imaging and spectroscopic arguments the fraction of the 1.8 MeV emission relating to the Vela SNR, (ii) to study the source of hard emission with power-law spectrum (index ~ –1.6) observed up to 400 keV by non-imaging instruments and supposed to originate from the compact synchrotron nebula surrounding PSR B0833-45.

Vela X-1, the archetypal wind-fed accreting pulsar. The high sensitivity of INTEGRAL in a wide bandpass will offer the unique opportunity to clarify the surprising appearance of the cyclotron resonance scattering features (a coupling factor > 2 between fundamental and second harmonic) in recent hard X-ray observations of Vela X-1.

GRS B0834-430, an unusual Be-star binary accreting pulsar. After years of bright hard X-ray outbursts, whose recurrence time of ~ 105 days was interpreted as the orbital period of the system, no further outbursts have been observed since July 1993. Be/X-ray binaries typically burst near periastron, therefore fruitful INTEGRAL observations of this hard transient of unusual behaviour should take place around 02/06/2002, 16/09/2002, 31/12/2002, 15/04/2003, 30/07/2003 and 13/11/2003.

Nova Vel 93, a black-hole X-ray nova in quiescence. Even if this confirmed black-hole X-ray nova is located off the proposed pointing direction, the INTEGRAL Vela survey will test the hard flux of its possible quiescent emission down to significant low values.

In addition to the target sources listed above, the persistent source (Vela region) observation intends to depict and study the diffuse 1.8 MeV interstellar source that may reflect the cumulative emission from an active region extending from the nearby Vel OB2 association to the more distant Vela molecular ridge. A few unidentified EGRET sources, possibly related to massive stars, will be also surveyed.

4. Detailed observing strategy

The pointed observations will be targeted at sources from three different categories:

- unknown transient sources (Section 1.2),
- known transient sources (Section 1.2), and
- persistent source - the Vela region (Section 4.3)

For year 1 the following split of CP guaranteed observing time (total for year 1 = 2.7×10^6 s, Table 1) has been allocated: 1.7×10^6 s for unknown and known transient sources, 1.0×10^6 s for the Vela region (persistent source).

4.1 Trigger criteria for unknown transient sources

The criteria for these sources triggering CP follow-up observations with INTEGRAL are listed in Table 4.

4.2 Trigger criteria for known transient sources

Below and in Table 5 we list criteria for these sources triggering CP follow-up observations with INTEGRAL:

- **GRS 1915+105**

Normal intensity level: around 100 mCrab (20 - 100 keV) and about 300 mCrab between 5 and 12 keV.

TOO trigger: Flux exceeding a threshold of 500 mCrab @ 10 keV and 300 mCrab @ 30 keV.

- **GROJ 1655-40**

Normal intensity level: 0 (off)

TOO trigger: Flux exceeding a threshold of 300 mCrab @ 100 keV.

- **1E 1740.7-2942**

The source was observed to have three different states

- standard: 120 mCrab (40 - 150 keV)
- low: 16 mCrab (40 - 150 keV)
- hard: $(0.5 - 1) \times 10^{-2}$ photons $\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ (300 - 600 keV) [~200 keV broad line emission!]

TOO trigger: Flux above 200 mCrab at 40 - 150 keV for continuum and/or
flux above 5×10^{-3} photons $\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ at 300 - 600 keV [broad line]

- **Cyg X-1**

Normal hard X-ray (~30 - 100 keV) intensity level: 1 Crab

TOO trigger: Flux below 400 mCrab for possible onset of ‘soft’ state. Flux above 2 Crab for more than a day for flare.

- **Cyg X-3**

Normal hard X-ray (20 - 100 keV) intensity level: 125 mCrab

TOO trigger: Flux above 400 mCrab. If the flux goes below 10 mCrab for several days, this is a hint that a major flare is coming.

- **GX 339-4**

Normal intensity level (hard state):

200 mCrab (35-150 keV), 100 mCrab (3-10 keV)

TOO trigger:

1) “flare” - hard flux approaches the 400 mCrab level

2) “soft” state - hard flux below 50 mCrab, but soft flux at the normal level or above (up to 800 mCrab)

3) “off” state - both hard and soft fluxes below 30 mCrab

- **Mrk 501**

Normal intensity level (hard state): EXOSAT flux about 3×10^{-11} ergs cm^{-2} s^{-1} (2 - 6 keV).

TOO trigger:

INTEGRAL TOO observation will be triggered from external observation if reported source flux > 1 Crab @ E> 30 GeV.

4.3 Strategy for Vela region (persistent source observation)

The target pointing will be at l = 265 deg, b = 0 deg, with a 5 × 5 dither pattern (30 minutes exposure per pointing) and 10^6 s total exposure. The instrument modes for Vela region observation are nominal, i.e.: SPI (photon-by-photon), IBIS (photon-by-photon [ISGRI], histogram [PICSIT]), JEM-X (full imaging), OMC (normal).

Table 4: Unknown transient sources (CP TOO follow-up observations)

Source	Priority[a]	Frequency	Trigger criterion	$T_{int,min}$ (s)	Inst. mode & dithering	Response alert → observation	Repeated obs?	T_{total} (s)	Trigger from
Unknown X-ray novae (e.g. Novae Mus)	2	0.5 / y	(1) flux < 10 keV at 1 Crab during outburst AND high energy detection, e.g. 0.5 Crab @ 100 keV (IBIS), 300 mCrab @ 60 keV (SPI) (2) flux < 10 keV at 3 Crab during outburst if no high energy data available.	Type 1: 8×10^5 Type 2: 4×10^5	Nominal[b], 5×5 rectangular pattern	One Type 1 observation as soon as possible, no later than 5 days after outburst. Additional Type 1 observations to be considered if source exhibits rare features such as relativistic outflows.	A series of *n* Type 2 observations with $2<n<5$ spaced by 30 days, starting 30 days after outburst	1.6×10^6	internal and/or external
SN Ia	2	0.5 / y	$m(V, peak) < 13^m$ $F_{847} \sim 10^{-5}$ ph $cm^{-2}s^{-1}$	10^6/observation	Nominal[b], 5×5 rectangular pattern	1: immediately 2: 100 d later	2 observations	2×10^6	external
Classical Novae	2	0.3 / y	$m(V) < 7^m$ $F_{1275} \sim 10^{-4}$ ph $cm^{-2}s^{-1}$ $F_{478} \sim 10^{-5}$ph $cm^{-2}s^{-1}$	10^5/observation	Nominal[b], 5×5 rectangular pattern	1: few (<5) days after nova event for 511 keV (line/cont) 2: Within 30 d after event for 478 keV 3: ~ 2 months after event for 1275 keV (intensity/shape).	3 observ. 1: 10^5 s 2: 10^5 s 3: 10^6 s	1.1×10^6	external
Local group SNII	1	0.05 / y	various	10^6/observation	Nominal[b], 5×5 rectangular pattern	1: after 100d 2: after 200d 3: after 300d	3 observations	3×10^6	external

[a] Highest priority = 1, lowest priority = 4 (priorities also dependent on actual flux of trigger), see also Table 5

[b] Nominal instrument modes are: SPI (photon-by-photon), IBIS (photon-by-photon [ISGRI], histogram [PICSIT]), JEM-X (full imaging), OMC (normal)

Table 5: Known transient sources (CP TOO follow-up observations)

Source	Priority[a]	Frequency	Trigger criterion	$T_{int,min}$ (s)	Inst. mode & dithering	Response alert → observation	Repeated obs?	T_{total} (s)	Trigger from
Superluminal jet sources (e.g. GRS 1915, GROJ1655-40)	2	0.5 / y	Section 4.2	10^5/observation	Nominal[b], 5×5 point rectangular	1: asap 2: ~ days	2 obs.	2×10^5	internal and/or external
Galactic transient events (e.g. 1E 1740, Cyg X-1, GX 339-4, GX 1+4)	1	1.0 / y	Section 4.2	10^5/observation	Nominal[b], 5×5 point rectangular	1: asap[c] 2: 1 day[c] 3: 2 weeks	3 obs.	3×10^5	internal and/or external
AGN/Blazars in outburst	3	0.5 / y	Section 4.2	10^5/observation	Nominal[b] 5×5 point rectangular	3 observations 10^5 s each, separated by 1 month	3 obs.	3×10^5	internal and/or external

[a] Highest priority = 1, lowest priority = 4 (priorities also dependent on actual flux of trigger), see also Table 4

[b] Nominal instrument modes are: SPI (photon-by-photon), IBIS (photon-by-photon [ISGRI], histogram [PICSIT]), JEM-X (full imaging), OMC (normal)

[c] Note that TOO turn-around time may be up to 36 hours, so observation 1 (“asap”) and observations 2 (“1 day”) may be combined into one observation

5. Exposure time and sensitivities

For TOO follow-up observations, the estimated exposure times and (detection) sensitivities are summarized in Section 4.2, Table 4 and Table 5 above.

Studies of point sources and nucleosynthesis studies of the Vela region require 10^6 s. The continuum sensitivities (3σ) obtainable during that observation in the 100 keV to 1 MeV range would be (20 to 1.5) $\times 10^{-7}$ photons cm^{-2} s^{-1} keV^{-1} for SPI and (5 to 6) $\times 10^{-7}$ photons cm^{-2} s^{-1} keV^{-1} for IBIS, while JEM-X would achieve ~7×10^{-6} photons cm^{-2} s^{-1} keV^{-1} in the 3 to 30 keV range.

For line studies SPI will achieve a 3σ sensitivity of ~7×10^{-6} photons cm^{-2} s^{-1} for narrow lines in the 100 keV - 2 MeV region.

V. 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 AO documents on *INTEGRAL Science Data Rights* and *INTEGRAL Manual*.