INTEGRAL

Announcement of Opportunity for Observing Proposals (AO-3)

INTEGRAL Guaranteed Time

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based upon inputs from:
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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 for AO-3

The Core Programme for AO-3 consists of various elements:

- Observations of the Galactic Central Region, including:
  - Deep exposure of the Galactic Centre
  - Deep exposures of Galactic spiral arm regions Scutum and Norma
  - Galactic latitude profile scans
- Frequent scans of the Galactic plane (Galactic Plane Scans, GPS)
- Deep extragalactic survey
- Follow-up observations of (yet) unknown TOO's

This document describes in detail, for each CP element, the scientific rationale, the detailed observing strategy, exposure times and estimated sensitivities.

It should be noted that all CP elements, except follow-up observations of (yet) unknown TOO's, are considered as "survey observations" (see AO document on *Science Data Rights* for further details).

1. The ISWT: J.-P. Roques/CESR Toulouse, V. Schönfelder/MPE Garching, P. Ubertini/IAS Rome, F. Lebrun/CEA-Saclay, M. Mas-Hesse/INTA Madrid, N. Lund/DSRI Copenhagen, T. Courvoisier/ISDC Versoix, N. Gehrels/NASA-GSFC, S. Grebenev/IKI Moscow, W. Hermsen/SRON Utrecht, G. Palumbo/U Bologna, J.Paul/CEA-Saclay, R. Sunyaev/IKI Moscow, B. Teegarden/NASA-GSFC, C. Winkler/ESA-ESTEC.

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 Time allocation for CP elements in AO-3 (Table 1) has been derived, assuming that science observations will only be performed above an altitude of 60,000 km prior to perigee entry and above 40,000 km following perigee exit. Scheduled observations during AO-1 and AO-2 have been used to refine pre-launch estimates.

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).

It has to be noted that in-flight calibrations during the nominal mission phase may occur like it was done during AO-1 and AO-2. 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 and General Programme (open) time. The total amount of that required time is yet to be determined.

Table 1: Time allocation for CP elements in AO-3

Item	Time [Ms]
Estimated total scientific time available for AO-3 (18 months)	36
Core Programme share for total scientific time in AO-3 (25% out of 36 Ms), which is broken down as follows:	9
• Galactic Central Region, including:	4.8
- *Galactic Centre*	*1.3*
- *Norma spiral arm region*	*0.8*
- *Scutum spiral arm region*	*1.4*
- *Galactic latitude profile scans*	*1.3*
• GPS	2.1
• Deep extragalactic survey	1.0
• TOO follow-up observations[a]	1.1

a.Note that another 1.5 Ms (bonus) time have been identified for more TOO follow-up observations. In case those observations will be scheduled, the required time will be subtracted from other CP elements. The reader is also referred to the AO document on *Science Data Rights*.

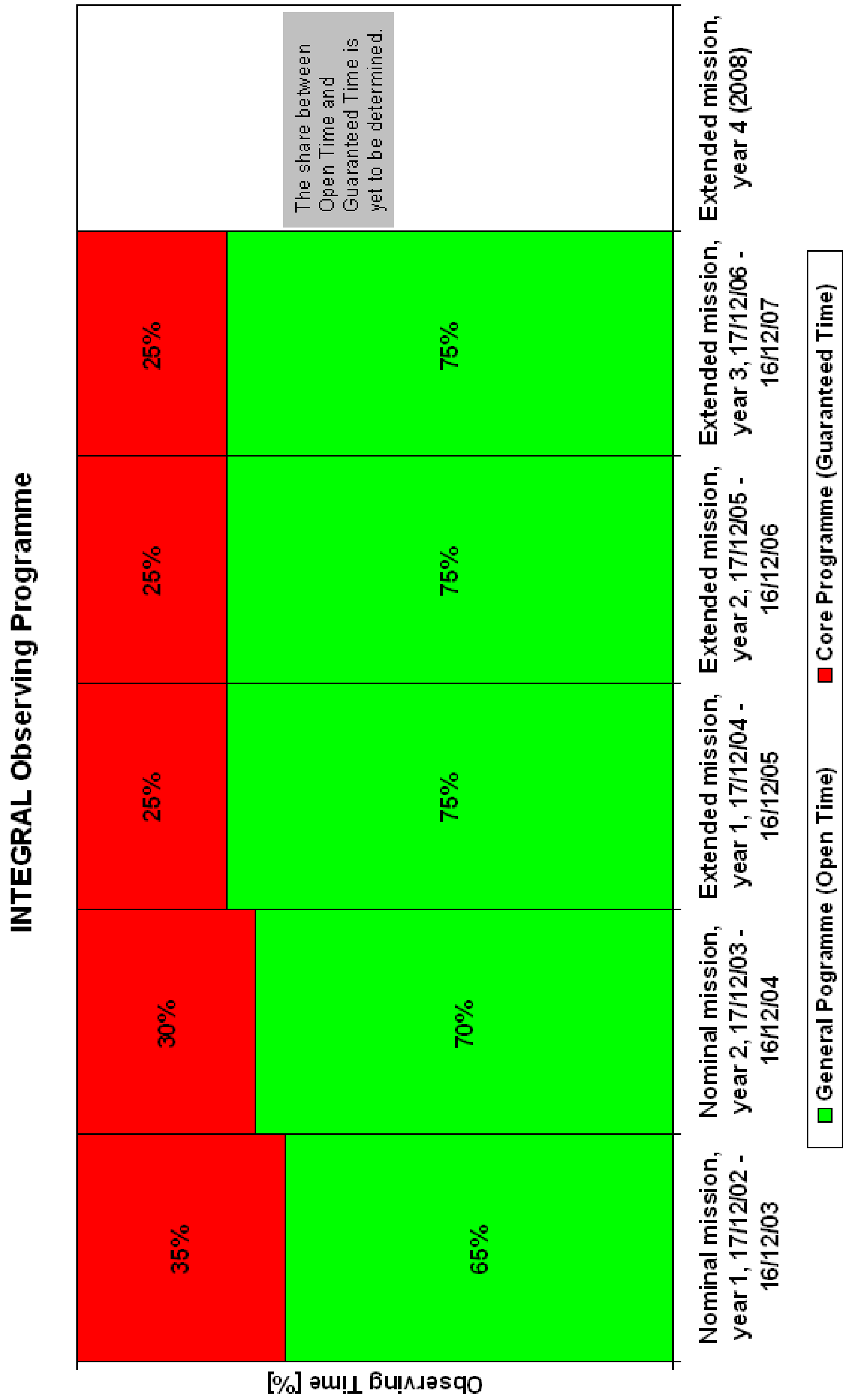

Figure 1. *Breakdown of INTEGRAL observing time. Launch took place on 17 October 2002. Nominal mission began on 17 December 2002.*

II. Studies of the Galactic Central Region

1. Introduction

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.

Early INTEGRAL results from the survey have revealed a 511 keV map from the galactic Centre region and a clear detection of the narrow 1.8 MeV line from ^{26}Al. Other isotopes such as ^{60}Fe produce lines which are thought to be detectable by INTEGRAL. Several interesting emission regions in or near the Galactic plane have been identified by CGRO/OSSE and CGRO/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).

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 survey will resolve isolated point sources with arcmin location accuracy and provide source spectra with high energy resolution.

INTEGRAL observed the Galactic Centre region 3 times along the course of the spring and fall observations in 2003-2004. For the first year this corresponded to a total observing time of about 1.5×10^6 sec in the central part of the Galaxy Survey and resulted in the detection of 91 gamma-ray emitters. Searches for the counterparts allowed to identify all but 26 with known sources. Forty of identified sample are accreting binary system with low mass companion as foreseen being the Galactic Bulge a region populated by old stars and also as expected by the more recent results from BeppoSAX and RXTE. The remaining sources are high mass system (7), radio pulsars (2), Supernova remnants (2), 1 millisecond pulsar, 1 Soft gamma-ray repeater and 1 Seyfert galaxy while 11 sources are still of unknown type and need to be studied in further details. An interesting result is that the new discovered sources show a spectrum significantly harder with respect to the know binaries ones, possibly indicating a new emerging population of hard sources. (Lebrun et al. Nature, 2004, 428, 293). The combined BeppoSAX and RXTE observations within 20^o from the Galactic Centre in the period 1996-2002 list 36 transient sources active for at least a few hours. But for 2 not obvious cases, these sampled transient resulted to be low mass system, most (22) with a neutron star as compact object thanks to detected timing signatures, while only 6 are black hole candidates. The detection of many type I X-ray bursts from 54 sources of which 21 new Bursters, have increased the X-ray burster population by about 50% from the pre-BeppoSAX/WFC era (in't Zand et al., Nuclear Physics B, Volume 132, p. 486,2004). It is also interesting to note that only 8 out of the 36 transients showed peak fluxes in excess of 0.2 Crab in the X-ray band while many (13) are about 0.05 Crab and even fainter. Almost half of these transients are recurrent with different time scales between 1 year and up to 20 years implying that a large fraction of the LMXRB transients have been discovered within 20^{o} of the Galactic Centre at energies lower than 30 keV, while INTEGRAL is now detecting the harder sources.

For the AO-3 cycle the observation of the Galactic Central Region has been split in four different separated scans: the Galactic Centre (1.3 Ms), the Scutum (1.4 Ms) and Norma (0.8 Ms) arm and the GC latitude scan (1.3 Ms). These are described in more detail in the following chapters.

III. Observations of the Galactic Centre

1. Scientific rationale

The Galactic Centre region has been already observed in the two first cycles of the INTEGRAL Core Programme through the Galactic Centre Deep Exposure. These observations have provided the most important results to date of the INTEGRAL mission, namely the resolution of the Galactic emission in compact sources, the discovery of a new class of obscured sources, the discovery of emission from the Sgr A* region and the measurement of the extent of the 511 keV line emission.

The 3rd cycle Core Programme will pay more attention to other regions (Galactic arms, high latitudes etc.), however, it is necessary to re-observe the Galactic Centre not only to pick up new variable sources but also to reach a better sensitivity in particular with an improved observing strategy that minimizes the systematic uncertainties. This improved sensitivity will allow:

- the detection of diffuse continuum emission (15-200 keV) or the detection of weaker compact sources and the setting of a more stringent limit on the diffuse continuum emission in this range
- to monitor the emission in the Sgr A* region in an attempt to detect a high energy outburst and to extend at higher energy the spectral measurements of this particularly hard source.
- to better constrain the morphology of the 511 keV line emission that is essential to pin point its origin (light dark matter, point sources, etc.)
- to monitor the micro-quasars 1E1740.7-2942 (weak long term periodic modulation, high energy transient emission) and GRS1758-258
- to monitor the many bursters lying in the Galactic bulge (high energy tails as in GS 1826-238 and 4U1812-12)
- to measure the spectra of known supernova remnants (G347.3-0.5, G11.2-0.3, Kepler)
- to detect unknown young supernova remnants through their ^{44}Ti line emission.

We note, that one of the rationales for changing the GCDE from previous AO's was to give more opportunity for GC observations to the open time programme. The decrease in Core Programme open time of the GC region (Table 1) for AO-3 gives therefore more open programme opportunity for this important region.

2. Observing strategy

Most of the scientific objectives rely on the improvement of the ISGRI sensitivity that is presently limited by the residual background structures. We propose to perform two 5x5 dither grids (Figure 2) around the Galactic Centre. With a total observing time of 1.3 Ms, each grid point can be observed during 26 ks (including slews). With a 2.17^{o} step, the slew time should be around 120 s.

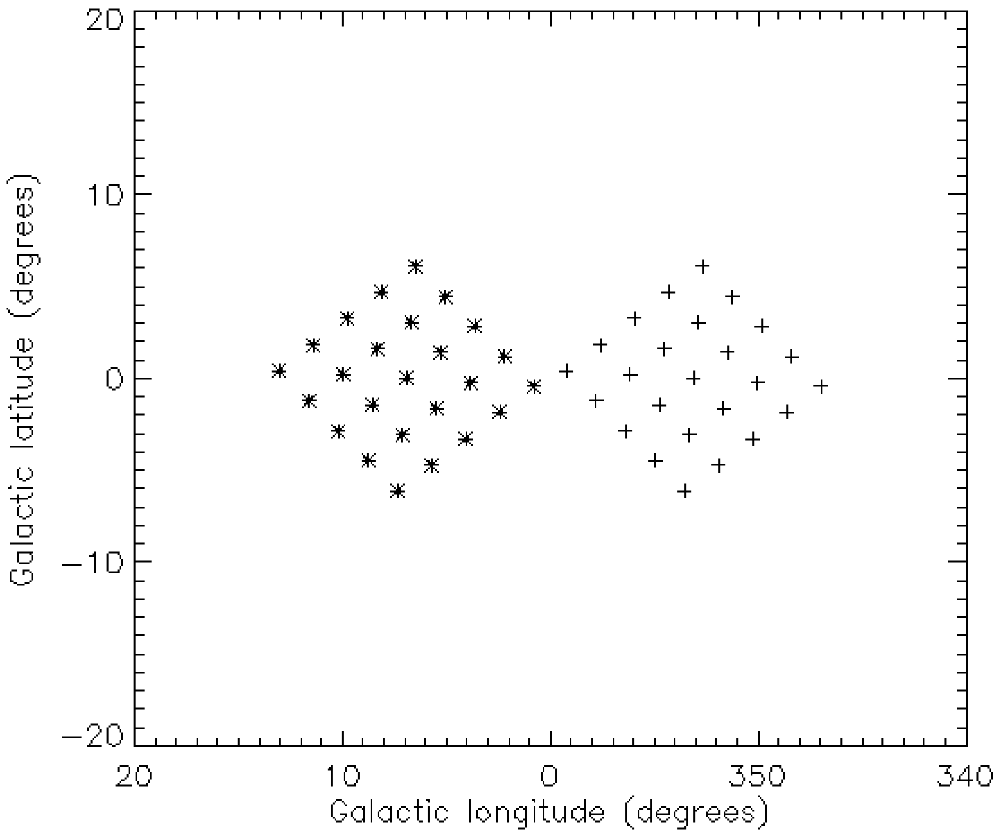

Figure 2. *Grid of pointings for the GC observations: 500 pointings of 2300 s each can be performed. Each 5x5 grid is therefore executed 10 times. Each grid will be shifted from the previous one by a small offset*[1]*.The centres of the grids are along the Galactic plane, at 6.9^{o} on both sides from the Galactic Centre. The instrument axes are usually inclined by 58^{o} to 62^{o} with respect to the Galactic plane, therefore the grid axes should be inclined by 47^{o} to 51^{o}(11.3 ^{o} with regard to the instrument axes). The grid step size is 2.17^{o}, optimal for the ISGRI image uniformity.*

The exposure map resulting from these GC observations is shown in Figure 3.

1.The amount of this shift is about 0.3^{o} after each grid cycle. This shift improves the IBIS background uniformity. Details are provided in the internal INTEGRAL document IN-IB-SAP-RP-077.

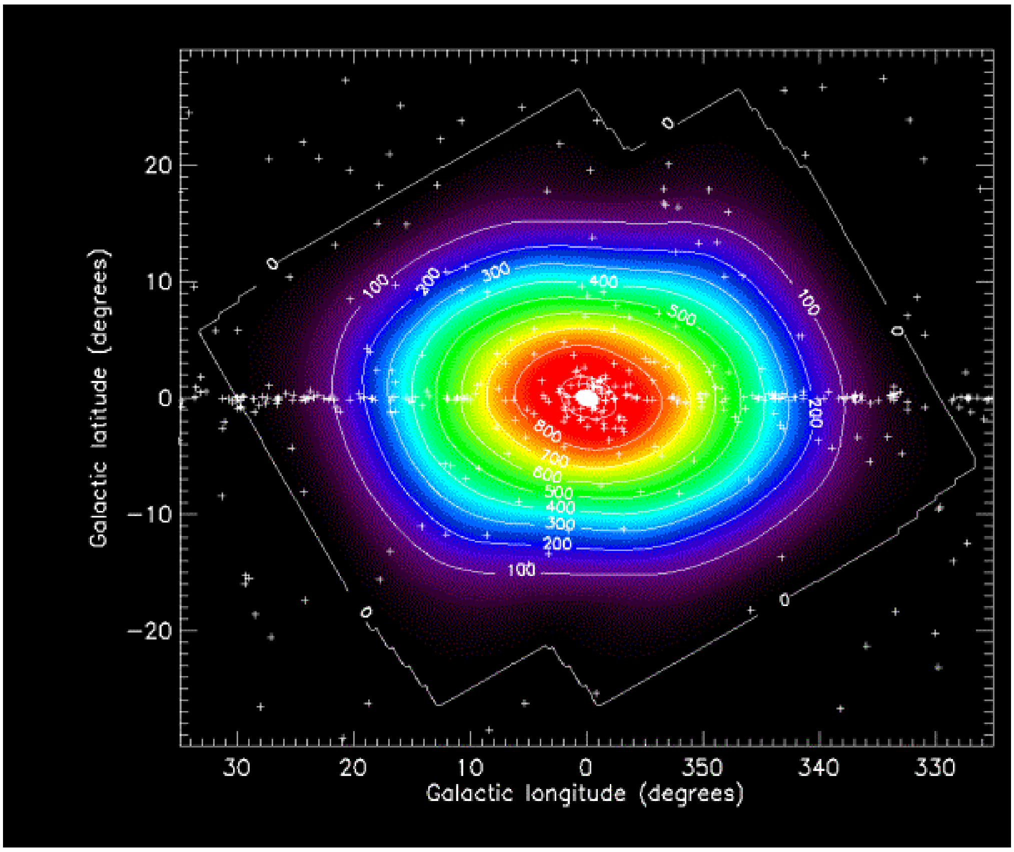

Figure 3. *Exposure map resulting from these GC observations. The contours are labelled in ks. High energy sources positions are indicated by crosses***.**

IV. Observations of the inner spiral arms of the Galaxy: Scutum and Norma

1. Scientific Rationale

The inner parts of the Galaxy have already been observed in the two first cycles of the INTEGRAL Core Programme providing monitoring of about a hundred sources and first detection of a number of sources at high energies. During AO-3 the monitoring of the inner parts of the galaxy (Galactic Centre region and latitude scans) will be complemented by a monitoring of the inner arms of the galaxy that were not optimally observed using the GCDE pattern used during the first two AO’s.

One of the important output of the Core Programme has been the detection of a high density of new sources in the Norma arm of the galaxy. Nine new sources have been detected within less than 15^o of galactic longitude. One source is a transient, all other are persistent. At least several of the persistent sources are highly absorbed and this is probably the reason why they were not known before INTEGRAL. The persistent sources do vary on time scales of months and also - for the brightest ones - on time scales of hours. The sources are being studied and follow-up programs have been started in the X-rays and infrared domains.

The follow-up of those sources and discovery of new ones is one of the motivation to concentrate part of the Core Programme time on the inner galactic arms.

Monitoring includes the 50 sources detected by INTEGRAL in the Scutum region and the 44 sources in the Norma region (in particular the micro-quasars of the Norma region 4U1630-47, XTE J1550-564; and GX 339-4, GRS1915+105, SS433 and GRS1758-25 in the Scutum region) and to possibly discover new transient events. The list of sources detected by INTEGRAL so far is shown in Section 2.1. Finally, the uniformity of the effective exposure of the inner Galaxy obtained so far will be further improved for statistical and diffuse emission studies.

2. Observing Strategy

In order to obtain a substantial coverage of the two regions and to reach the required sensitivity, the following strategy will be implemented:

- Scutum, observing time: 1.4 Ms, Co-ordinates of grid centre: $l = 25.0^o$, $b = 0.0^o$
- Norma, observing time: 0.8 Ms, Co-ordinates of grid centre: $l = 335.0^o$, $b = 0.0^o$.

Each of the two regions will be covered by identical grids (Figure 4) composed of 10 (longitude) x 5 (latitude) points with step size of 2.17^o each in closed loop slew mode (slew time ~ 120 s). The basic strategy is similar to the one for the GC to optimize the treatment of background structures.

A full grid is then composed by 10 x 5 = 50 pointings of ~2ks each in order to have a total observing time of about 100 ks/grid (including slew time). Each grid will be shifted from the previous one by a small offset (see footnote to caption of Figure 2).

During the three visibility periods in AO-3, the recommended observation strategy is as follows:

- AO-3, 1st period: 500 ks on Scutum (5 grids), 400 ks on Norma (4 grids)
- AO-3, 2nd period: 500 ks on Scutum, 400 ks on Norma
- AO-3, 3rd period: 400ks on Scutum.

In this way during each of the three observation periods of AO-3 we have an integer number of full grids for both Scutum and Norma.

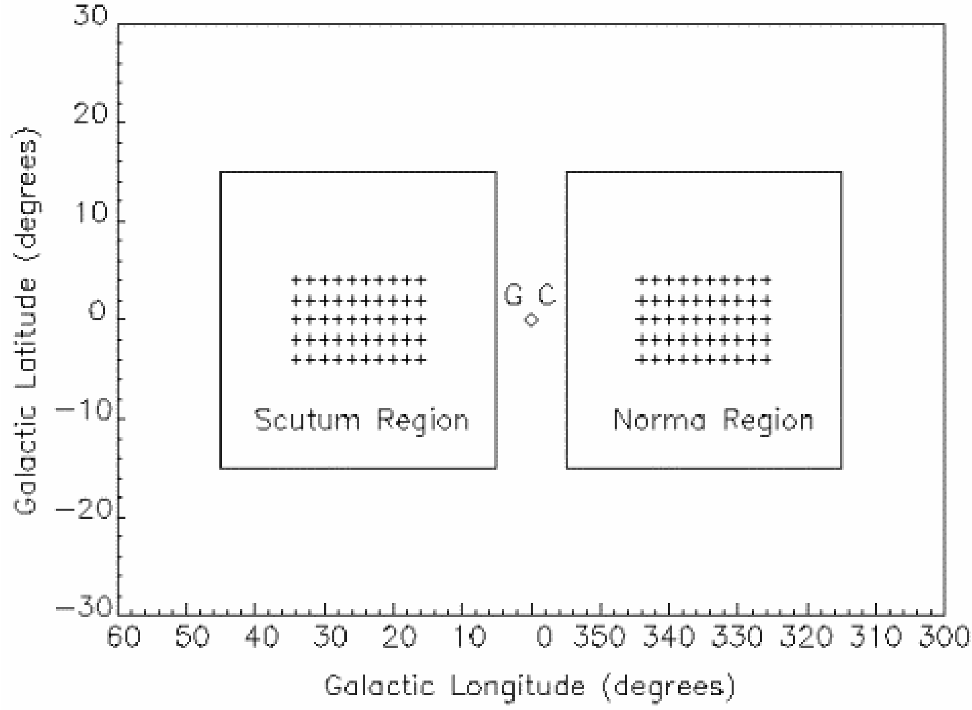

Figure 4. *Grid of pointings for Scutum and Norma arm observations. Each cross is 2.17^{o} apart. The centres of the two grids are l=25.0^{o}, b=0.0^{o} and l=335.0^{o}, b=0.0^{o}, respectively. The boxes outside each grid represent the IBIS 50% response Field of View. The sky region covered by the boxes may change according with the actual roll angle depending on the sun aspect angle at the time of the observations*

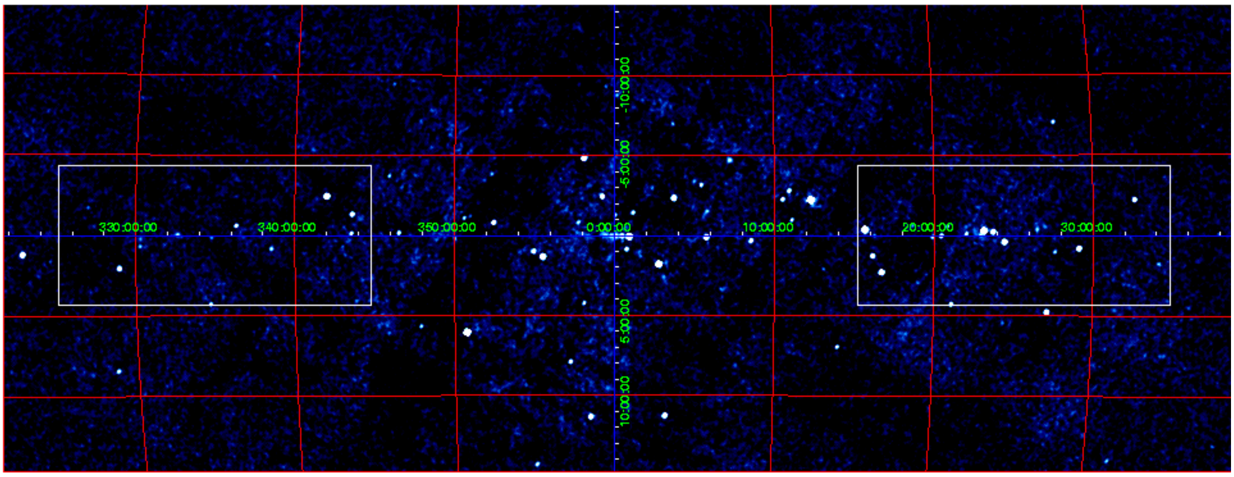

Figure 5. *Scutum and Norma regions overlaid on the IBIS survey picture. The white rectangles in the figure outline the grid region***.**

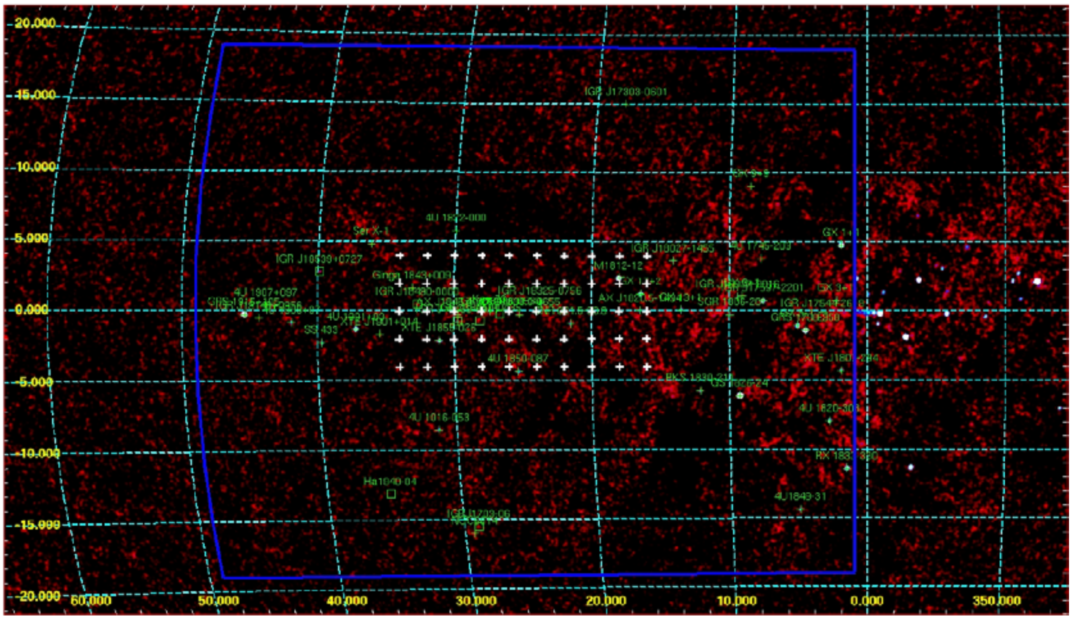

Figure 6. *Zoom of the Scutum region with the 10 x 5 pointing grid overlaid: the field is centred at co-ordinates l=25.0^{o}, b=0.0^{o}. The green crosses are sources detected by the IBIS survey. The blue contour is the IBIS partially coded FOV (zero response)***.**

2.1 INTEGRAL detected sources in the Scutum and Norma regions

<u>Scutum</u>

	l	b	source
1)	17.922594	14.992897	IGR J17303-0601
2)	8.522202	9.0376197	GX 9+9
3)	1.9401674	4.7987908	GX 1+4
4)	2.2947167	0.79440047	GX 3+1
5)	7.7143271	3.8115135	4U 1745-20
6)	37.5759793	0.77150182	IGR J17597-2201
7)	5.0804816	-1.0139331	GX 5-1
8)	4.5095035	-1.3604317	GRS 1758-258
9)	9.0818001	1.1557026	GX 9+1
10)	9.4099252	1.0437545	IGR J18027-2016
11)	14.112199	3.6619318	IGR J18027-1455
12)	1.9201786	-4.2777427	XTE J1807-294
13)	10.002614	-0.21700834	SGR 1806-20
14)	13.51559	0.11353564	GX 13+1
15)	18.027694	2.3961337	M1812-12
16)	16.43351	1.2779093	GX 17+2
17)	16.488798	0.069879619	AX J1820.5-1434
18)	2.7856165	-7.9273893	4U 1820-303
19)	29.938221	5.7878319	4U 1822-000
20)	9.2735883	-6.0850138	GS 1826-24
21)	23.70151	0.56934192	IGR J18325-0756
22)	21.499002	-0.87592048	SNR 021.5-00.9
23)	12.144902	-5.7200892	PKS 1830-211
24)	1.5343915	-11.367204	RX 1832-330
25)	25.252884	-0.20216995	AX J1838.0-0655
26)	36.113807	4.8360867	Ser X-1
27)	27.379683	0.0056615711	Kes 73
28)	33.059527	1.6889414	GS 1843+009
29)	29.714795	-0.23302988	AX J1846.4-0258
30)	29.755884	-0.7480018	IGR J18483-0311
31)	25.349001	-4.3236792	4U 1850-087
32)	31.075304	-2.0874538	XTE J1855-026
33)	35.410902	-1.6383777	XTE J1901+014
34)	37.181078	-1.2509938	4U 1901+03
35)	43.745409	0.48383793	4U 1907+097
36)	41.888883	-0.81274762	4U 1909+07
37)	39.692897	-2.2397958	SS 433
38)	44.293812	-0.45974848	IGR J19140+0956
39)	45.363087	-0.21713321	GRS 1915+10
40)	31.342591	-8.5088619	4U 1916-053
41)	4.9572	-14.3542	4U1849-31
42)	28.9948	-15.485	RX1940-1025
43)	29.3422	-16.003	NGC6814
44)	17.9198	14.9977	IGR1703-06
45)	3.2360898	-0.33592196	IGR J17544-2619
46)	26.670123	-0.17333349	IGR J18406-0539
47)	28.119727	-0.66006148	IGR J18450-0435
48)	29.756014	-0.74615471	IGR J18483-0311
49)	32.653996	0.54242868	IGR J18490-0000
50)	39.84724	2.8455094	IGR J18539+0727

Also a total of 27 sources are located in the FOV, some of which are recurrent transients, listed below:

4U 1730-22, 4U 1731-26, RXJ1744.7-2713, EXO1745-248, EXO1747-214, SLX1749-285, AX1749.2-2725, GROJ1750-27, XTE 1806-246,4U1807-10, SAXJ1810.8-2609, SAXJ1819-2525, RX1826.2-1450, Sct X1, GS1839-06,GS1839-04,1E1841-045,RX 1838.4 0301,AX1845.0-0433, AX1845.-024, EXO1846-031, XTE1856+056, XTE1858+034, 4U1905+00, Ha1940-04, XTE 1906+09, Aql X-1.

Norma

1) 4U1700-377
2) OAO 1657-415
3) 4U1630-47
4) GX 349+2
5) GX 340+0
6) H1705-440
7) GX 354-0
8) 1735-444
9) IGR J16318-4848
10) H1636-536
11) H1608-522
12) H1538-522
13) 1702-429
14) IGR J17252-3616
15) IGR J16393-4643
16) 4U1516-569
17) GX 339-4
18) IGR J17091-3624
19) IGR J16418-4532
20) SAXJ1712.6-3739
21) IGR J16479-4514
22) IGR J15479-4529
23) 4U1626-67
24) IGR J16358-4726
25) H1624-490
26) H1746-370
27) XTE J1720-318
28) Cir galaxy
29) 4U1705-32
30) IGR J16207-5129
31) IGR J17254-3257
32) XTEJ1550-564
33) IGR J16195-4945
34) IGR J16167-4957
35) PSR 1509-58
36) NGC6300
37) IGR J17200-3116
38) IGR J17195-4100
39) PSR J1649-4349
40) AX J1700.2-4220
41) IGR J16558-5203
42) 4U1822-371
43) GRS1724-308
44) GRS1734-292

Also a total of 29 sources are located in the FOV, some of which are recurrent transients, listed below:

Cen X-2, TrA X1, 4U1543-624, 4U1556-605, SAXJ1603.9-7753, GRO1655-40, A1658-298, H1705-25, 4U1708-408, XTE 1709-267, XTE1710-281, H1711-339, M1715-321, RX171824.2-402934, XTE1723-376, KS1724-356, KS1730-312, GRS1737-31, KS1739-30, Rapid Burster, A1744-361,SAXJ1808.4-3658, 4U1417-624, SAXJ1452.8-5949, S1553-542, EXO1722-363, SAXJ 1752.3-318, 4U1755-338, XTE1755-324.

V. Galactic Latitude Scans

1. Scientific Rationale

Most of INTEGRAL observation time so far has been spent along the Galactic plane: this will lead to a precise determination of various diffuse emission processes along the plane (lines: 511 keV, Al^{26}, Fe^{60} and diffuse continuum emission).

However, the determination of the latitude profile of these emissions is of prime importance to discriminate between physical models. Up to now, with the current set of observations, it is difficult to give solid constraints on the Galactic latitude extension of the observed 511 keV emission.

The diffuse 511 keV Galactic emission is one important goal of this observation. Latitude profiles of the diffuse emission will permit tests for various positron production/annihilation models. As an example, in the light of recent dark matter positron production models, it will be possible to test the dark matter density profile.

2. Observing Strategy

The total exposure time for these Galactic latitude scans will be 1.3 Ms. Data from previous AO-s have been taken in a non-uniform manner: in particular the high latitude observations have been performed at different times than observations of the inner part. The difference between background models induces significant variations in the determination of the emission.

The method proposed here will lead to a systematic-free measurement of the Galactic latitude profiles. It consists of rapid latitude scans between latitude -30^o and +30^o. It is important to perform these scans within a short time interval, compared to time-scales of SPI background variations. In order to keep the imaging capabilities for point sources, we keep a standard step size of 2^o. If we assume 30 min pointing duration a single scan can be done in about 15 to 16 hrs. Each single scan should by preference be executed in a single pass, i.e. within one revolution.

Within these conditions a simple pattern is therefore:

i) For $l = -4^o$: scan from $b = -30^o$ to $b = +30^o$ in 2^o steps
ii) For $l = -2^o$: scan from $b = +30^o$ to $b= -30^o$ in 2^osteps
iii) For $l = 0^o$: scan from $b = -30^o$ to $b = +30^o$ in 2^o steps
iv) For $l = +2^o$: scan from $b = +30^o$ to $b = -30^o$ in 2^o steps
v) For $l = +4^o$: scan from $b = -30^o$ to $b = +30^o$ in 2^o steps

Here each consecutive scan is reverse from the previous one, this is useful if they are executed in sequence.

VI. 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).

The GPS scans executed during the first year of operations (INTEGRAL AO-1) were successful as 3 out of the 10 new INTEGRAL (IGR) sources were discovered between Jan. 29 and May 2, 2003 during GPS scans. CGRO and SIGMA have also 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 regular scans of the Galactic plane at 1 - 2 weeks frequency 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. 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, scientific objectives and performance during previous years into account. Basically the scans will be performed (Table 2) by executing a continuous “slew and stare” manoeuvre of the spacecraft along the visible (accessible) part(s) of the Galactic plane with an extension in latitude up to +/- 10^{o}. The angular distance between two “staring points” along the scan path is 7^{o}, the extremes in latitude of the pointings are at b = +/- 6.45^{o}. The scans will be performed in a saw-tooth pattern with inclination of 17.8^{o} with respect to the Galactic plane, each subsequent scan being shifted by 27.5^{o} in longitude. Note that the scan frequency will be one scan per 4 revolutions in the Galactic centre region ($270^{o}<l<360^{o}$; $0^{o}<l<90^{o}$), and reduced by a factor of 2 (one scan per 8 revolutions) for the intervals of Galactic longitude between $l = 90^{o}$ and $l = 270^{o}$ (anticentre region). During CP exposure of the spiral arms or other CP observations covering the plane (e.g. Galactic Centre, latitude scans) the GPS scans will ***not*** be executed. The accessible part of the Galactic plane depends on viewing constraints, including the solar aspect angle, and on the season of the year. Figure 7 shows the Galactic plane visibility for GPS scans. A schematic view of two consecutive scans in show in Figure 8.

Table 2: Baseline parameters of GPS scans during AO-3[a]

Parameter	Value	Notes
Solar Aspect Angle	+/- 40^{o}	
Slew mode	open loop	
Inclination wrt gal. plane	17.8^{o}	
Max galactic latitude	$\|b\| = 6.45^{o}$	
Step size along path	7.0^{o}	
Duration of 7^{o} slew	~ 220 s	Based on s/c specification
Time for initial slew prior to each GPS scan	780 s	Assumes a 30^{o} slew (140^{o}/hr) prior to each GPS scan.
Exposure per point	2200 s	
Exposure time/slew time	10.0	
Total (slew + exposure) per point	~ 2400 s	
Scan frequency	1 scan per 4 revolutions ($270^{o}<l<360^{o}$; $0^{o}<l<90^{o}$) 1 scan per 8 revolutions ($90^{o}<l<270^{o}$) ***No*** GPS scans during CP observations of spiral arm regions or other CP observations (e.g. GC, latitude scans) covering the plane.	

a. 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).

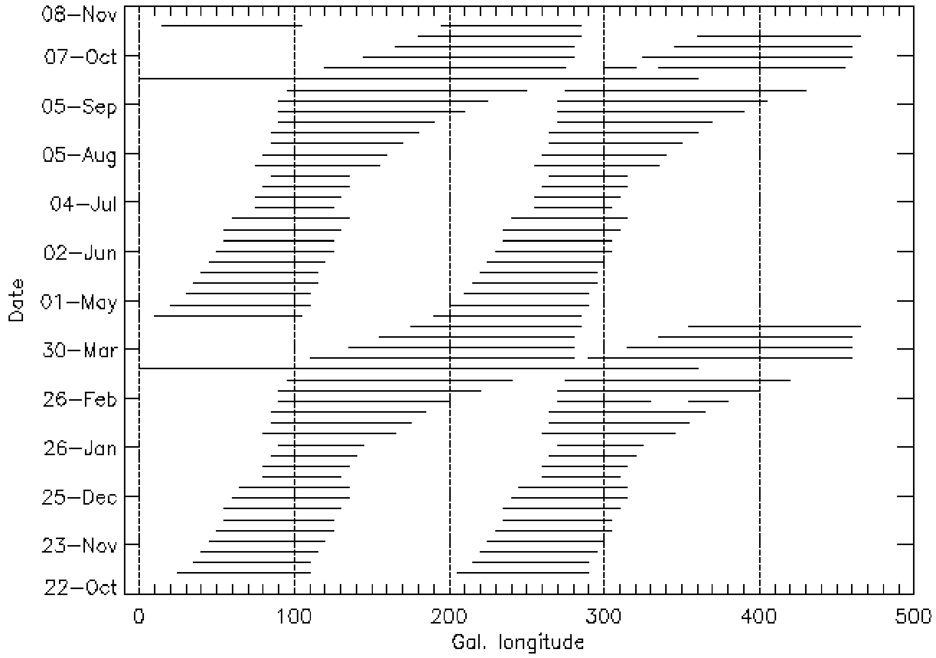

Figure 7. *General view of the visibility of the Galactic Plane for GPS scheduling purpose. The extent of the visible (i.e. accessible) part of the Galactic plane (with +/- 10^{o} in galactic latitude) is shown by the solid lines.*

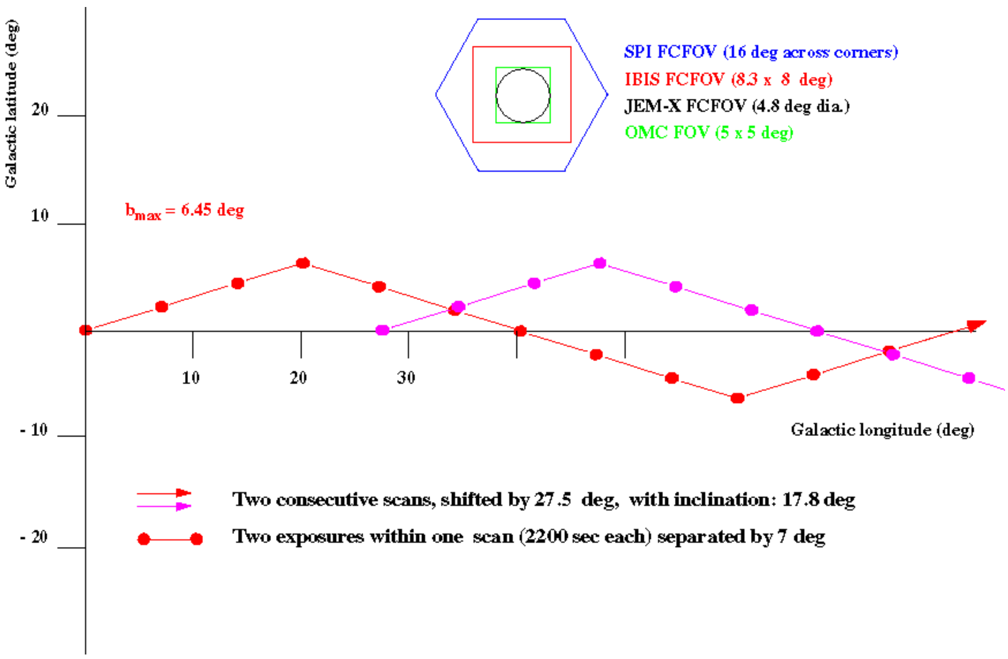

Figure 8. *Schematic view of two consecutive GPS scans***.**

In-orbit performance of INTEGRAL has been used to derive sensitivities. Table 3 lists the 5σ sensitivities relevant for transient detection and galactic plane mapping of diffuse continuum and line emission. The sensitivities for SPI, IBIS and JEM-X were calculated using in-orbit background in each instrument measured since launch. The IBIS number is for the low-energy ISGRI portion of the response and relevant for single pointings (2200 sec) in a scan. JEM-X is also quoted for single pointings. For SPI, with its wide field of view, the sensitivity is derived from analysis of sources seen in a single GPS scan: a source is seen ~3 times in a scan, hence the average exposure is ~6600 s, depending on the source position with respect to the scan path.

Table 3: Sensitivities achieved during previous GPS observations

Case	Exposure	Instrument	Energy Range	5σ Sensitivity
Single scan	2200 s	IBIS	(15-40) keV	35 mCrab
Single scan	2200 s	JEM-X	(5-20) keV	30 mCrab
Single scan	6600[a] s	SPI	(20-40) keV	68 mCrab
Yearly average[b]	10^5 s	SPI	1809 keV line	1.1×10^{-4} ph cm^{-2} s^{-1}

a.Due to its wide partially coded FOV, the same GPS point will be “seen” 3.3 times during a scan.
b.A point along the GPS scan receives on average a total exposure of 10^5 s

VII. Deep Extragalactic Survey

1. Scientific Rationale

Extragalactic sources of hard X-rays/soft γ-rays include AGN's (Seyfert and blazars), clusters, and gamma-ray bursts. The CP INTEGRAL deep extragalactic survey (Figure 9) aims to study all those types of sources. The selected field includes the Virgo cluster, the hard X-ray bright Seyfert type objects 3C 273, NGC 4388 and NGC 4593 and the blazar 3C 279 as well as more than 20 fainter high energy sources detected by previous missions.

This region of the sky has already been observed by INTEGRAL. The current observation will allow to study the variability of the brightest sources and to obtain a deep effective exposure (> 3 Msec) using all available data together.

This observation aims in particular at:

- detecting the high energy break in a few bright objects, in particular 3C 273 (which was unfortunately in a very low state during the previous years). Comparison with previous observations will allow to study the source variability and correlations with observation taken in other bands,
- monitoring the variability of 3C 279 and compare it with variability in other wavebands. During AO-1, INTEGRAL detected the source in a very low state at hard X-rays. New observation will help constraining the modelling of the plasma/jet properties,
- observing again NGC 4388 and NGC 4593 to obtain better spectral shape,
- obtaining the hard X-ray spectrum of a handful of sources at two epochs,
- combining the AO-3 data with previous INTEGRAL observations of the field to detect hard X-ray emission from about 20 extragalactic (known and unknown) sources (extrapolated from log N-log S), including several absorbed sources,
- probing if there is any high energy diffuse emission from the Virgo cluster besides emission from individual galaxies and constrain the cluster magnetic field,
- detecting gamma-ray bursts occurring in the field. There is a 30% probability that a gamma-ray burst will be observed during this observation. To observe GRB's outside of the galactic plane (which is rare with INTEGRAL) is an opportunity that should not be missed.

2. Observing strategy

The observing strategy has been chosen to observe Virgo, 3C 273 and 3C 279 using a rectangular dithering pattern of 5 x 12 pointings (dither step of 2.17^{o} degrees; 125 ksec per pattern) centred on RA (J2000) = 12^{h}34.5^{m} DEC = 03^{o}32' with an inclination of 10^{o} with respect to the equatorial coordinate system. The pattern will be repeated 4 times during the first and second visibility periods of the field during AO-3. The total exposure time is 1 Msec. A small offset (see footnote to caption of Figure 2) should be included between each pattern as for the standard 5x5 standard pattern.

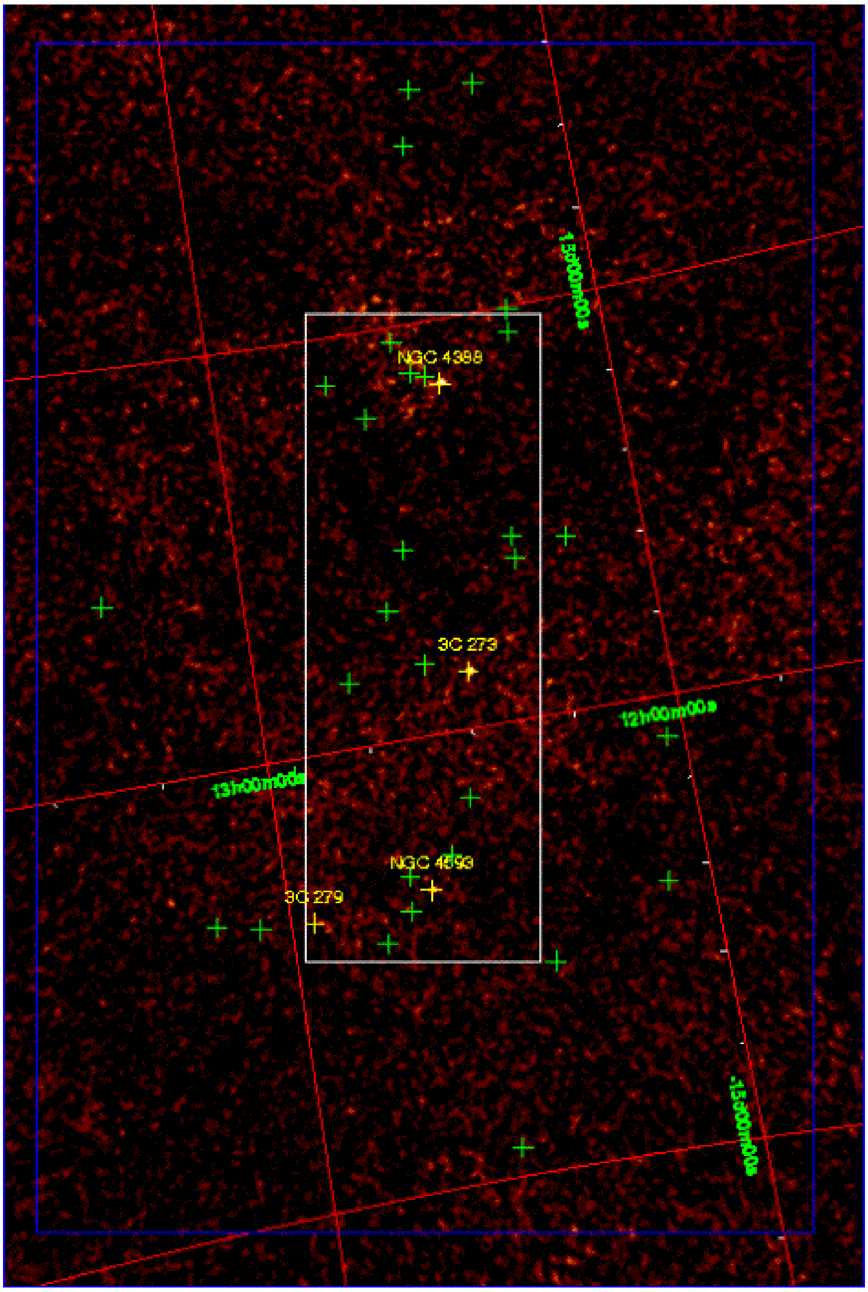

Figure 9. *Deep INTEGRAL extragalactic survey field: The yellow crosses show sources already detected by INTEGRAL. The green crosses show sources with known hard X-ray emission. The white rectangle shows where the pointing region will be located. The blue rectangle outlines approximately the PCFOV that will be covered by that observation (this will of course depend on the spacecraft's roll angle).*

VIII. Follow-up observations of TOO's

1. Introduction

Remaining Core Programme observing time will be devoted to follow-up observations on TOOs which have been detected during the CP survey observations (Section 1. on page 5) 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 high imaging 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*) and INTEGRAL has up to now successfully performed many TOO (open and core time) observations. 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 so far 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 CP TOO follow-up pointed observations in AO-3 will be targeted at unknown (new) transient sources with a total allocated CP observing time of 1.1 Ms. Note that another 1.5 Ms (bonus) time have been identified for more TOO follow-up observations if needed (see total required time as shown in Table 4). In case those observations will be scheduled, the required time will be subtracted from other CP elements. The reader is also referred to the AO document on *Science Data Rights*.

1.1 Strategy for selection of unknown 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 time allocation shall be used for unknown transient sources of the following type:

- Supernovae, type Ia
- local group Supernovae, type II
- classical novae
- previously unknown X-/γ-transients (X-ray novae, sources with NS or BHC characteristics)

whatever TOO event comes first. Trigger criteria have been defined (Table 4) so that these events listed above become scientifically an exceptionally unique - and for INTEGRAL important- target.

It is understood that some flexibility should be kept by the ISWT in case a **major** (“<u>once in a lifetime</u>”) **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 other CP observations 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.

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.*

In case **none** of the TOO events as described above take place during the AO cycle, the allocated time will be spent on other observations within the CP.

2. Scientific rationale

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 $^{56}Ni \rightarrow ^{56}Co \rightarrow ^{56}Fe$ 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 5000 km/s is assumed, the SPI sensitivity limit for detecting the 847 keV ^{56}Co-line is about 3.7×10^{-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 about 5 to 6 Mpc. Within this distance, one type Ia supernova can be expected about every five 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 Classical Novae

Some radioactive elements being synthesized during nova explosions have yet to be detected through gamma-ray line emissions. 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 (ONe) novae (Nova Her 1991, Nova Cyg 1992) as observed by CGRO established 2σ upper limits of ~ (2 to 3) $\times 10^{-5}$ 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 CO 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.

3. Observing Strategy

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

The observing (dither) strategy after trigger will be as follows, as default for all candidate TOO sources as listed in Table 4: All TOO follow-up observations will always start with the hexagonal dither pattern centred on the TOO target co-ordinates, then followed by one or more cycles of the (5x5 point) dither patterns, in accordance with the total TOO allocated time. The duration of each pointing will be computed by ISOC.

As an example for a 120 ks TOO observation, this will result in a 7 dither hexagonal plus two (5x5) dither patterns with 2105 s per pointing + slew. This will imply ~15 ks for the first hexagonal dither pattern and 105 ks for the last two 5x5 dither patterns.

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

Source	Frequency	Trigger criterion	$T_{int,min}$ (s)	Inst. mode[a] & dithering	Response alert → observation	Repeated observations?	T_{total} (s)	Trigger from
Unknown X-ray novae (e.g. Novae Mus)	0.5 / y	(1) flux > 500 mCrab at E< 10 keV during outburst <u>AND</u> high energy detection, 150 mCrab @ 100 keV (IBIS) (2) flux < 10 keV at 1 Crab during outburst if no high energy data available.	Type I: 3×10^5 Type II: 2×10^5	Dithering strategy for all TOO follow-up observations in this Table: see text in Section 3. on page 28	One Type I observation as soon as possible, no later than 5 days after outburst. Additional Type I observations to be considered if source exhibits rare features such as relativistic outflows.	Type I: 1 Type II: 2<*n*<4 observations spaced by 30 days, starting 30 days after outburst	1.1×10^6	internal and/or external
Sources with NS characteristics	few/y	flux > 50 mCrab @ 30 keV	2×10^5		Possibly within one week	2 more observations, each week	6×10^5	in and/or external
Sources with BHC characteristics	few/y	flux > 50 mCrab @ 80 keV	2×10^5		Possibly within one week	2 more observations, each week	6×10^5	in and/or external
SN Ia	0.2 / y	$m(V) < 10^m$ or distance < 10 Mpc	10^6/observation		1: immediately 2: 100 d later	2 observations	2×10^6	external
Classical Novae	0.2/ y	$m(V) < 6^m$ and distance < 1 kpc	2.4×10^6		Within 10 days after event for CO nova. 42 days after event for ONe nova.	no	2.4×10^6	external
Local group SNII	0.05 / y	various	10^6/observation		1: after 100d 2: after 200d 3: after 300d	3 observations	3×10^6	external

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

IX. 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*.