INTEGRAL

Science Operations Centre

Announcement of Opportunity for Observing Proposals (AO-4)

AO-4 Guaranteed Time

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1 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.

1.1 The Core Programme for AO-4

The Core Programme for AO-4 consists of deep observations of the Galactic Plane Region. This document describes the scientific rationale, the detailed observing strategy and exposure times. It should be noted that these observations are considered as "survey observations" (see AO document on *Science Data Rights* for further details).

1.2 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, 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 previous AO's have been used to refine pre-launch estimates.

It has to be noted, that scheduling of in-flight calibrations during the nominal mission phase will occur, like it was done during AO-1 to AO-3. 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.

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[1] *The ISWT: J.-P. Roques/CESR Toulouse, R. Diehl/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.*

Table 1 Time allocation for CP in AO-4

Item	Time [Ms]
Estimated total scientific time available for AO-4 (12 months duration)	24
Core Programme share (Figure 1) of total scientific time in AO-4	6

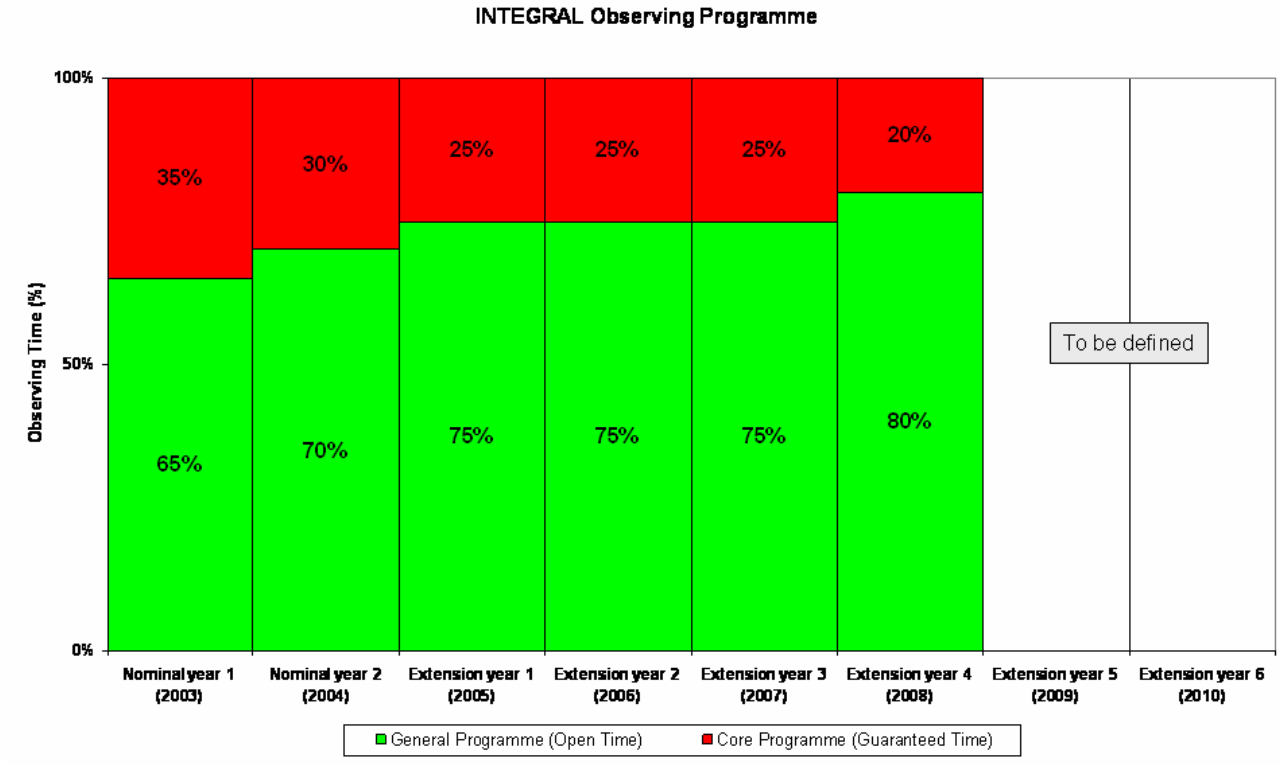

Figure 1 Breakdown of INTEGRAL observing time. Launch took place on 17 October 2002. Nominal mission (year 1) began on 17 December 2002.

2 Deep observations of the Galactic Plane Region

2.1 Scientific rationale

The INTEGRAL mission has produced a wealth of new scientific results[2]. Main achievements obtained so far are, or are based on, the first and second IBIS/ISGRI catalogues of sources (Bird et al., ApJ 607, L33, 2004, and ApJ 636, 765, 2006), the 511 keV all-sky map (Knödlseder et al., A&A 441, 513, 2005), and results on ^{26}Al (Diehl et al., Nature 439, 45, 2006). Many important results came from the deep observations of the Galactic Centre (Lebrun et al., Nature 428, 293, 2004, Bélanger et al. ApJ 636, 275, 2006) and the spiral arms including X-ray binaries (e.g. Lutovinov et al. A&A 444, 821, 2005) and new INTEGRAL sources (e.g. Kuulkers, astro-ph/0504625, 2005).

Besides understanding how individual objects work, the study of the collective properties of different high-energy sources in different stellar populations is becoming more and more important. INTEGRAL is pioneering these studies in the Milky Way at the high energies, retracing the work done in the past 30 years at energies below 10 keV's (Fabbiano, astro-ph/0511274, 2005).

At the end of the mission, the Galactic source catalogue will certainly be the reference used by future narrow field instruments (e.g. SIMBOL-X, Nustar, GRI). As such, the catalogue should be as complete and unbiased as possible. Therefore, Galactic source population studies require a rather uniform coverage of the disc. Nucleosynthesis studies as well as 511 keV studies have the same requirement. However, by the end of A0-3 (Summer 2006), as a result of both the open time (including TOO's) and Core Programme, the exposure of the Galaxy will be far from uniform (see Figure 2 and Figure 3).

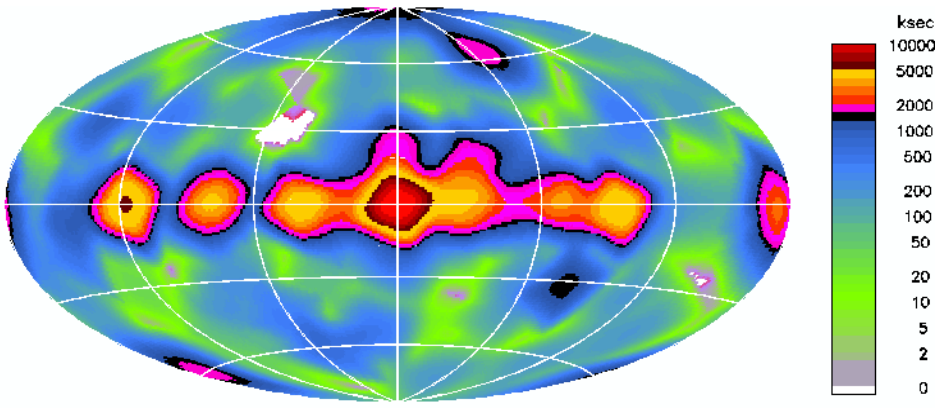

Figure 2 IBIS exposure map in galactic co-ordinates (fully and partially coded FOV) as expected (now) at the end of AO-3 (August 2006). ***Note that an updated map can be found on the ISOC WWW[3].***

It is most likely that the AO-4 open time will increase the contrast of the exposure map. In particular, the exposure on the Galactic Centre will certainly be close to 15 Ms just with the effect of the open time observations. Only the Core Programme part can be coordinated to avoid

[2] *An up-to-date list of publications can be found at http://integral.esac.esa.int/Publications/*
[3] *http://integral.esac.esa.int*

strongly underexposed regions detrimental to the above mentioned studies. In addition, one may consider the following points:

- Imaging results from long exposures (>5 Ms) may be limited by background residuals. We do not have so far a detailed view on the systematics for IBIS in longer exposures.
- Results from very long exposures (>15 Ms) on crowded regions may also be limited by source confusion (Galactic Centre).
- A significant gain in sensitivity is more easily obtained by observing the yet less exposed regions.
- The pointing and visibility/scheduling constraints require distributing the total observing time to not more than ~ 3 Ms in any given direction.
- Spiral arms are not precisely defined and known (e.g. spiral arm tangent $\Delta l \sim 5^o$).
- Imaging of diffuse emission obtained over substantially large sky regions is hampered by exposure contrasts.

Several regions of the Galactic plane have been identified (Figure 2) as particularly under-exposed. Bearing in mind that the available time of the Core Programme in AO-4 is limited to 6 Ms, it has been decided to focus on the four inner regions to achieve a minimum exposure at the end of AO-4 (i.e. over almost 5 mission years in total) of about 4 Ms on each of them (Figure 3). Therefore the AO-4 Core Programme observations are planned as shown in Table 2.

Table 2 AO-4 CP observations of the inner Galaxy

Observation	galactic longitude	galactic latitude	Exposure [Ms]
1	23^o	0^o	0.3
2	312^o	0^o	0.8
3	60^o	0^o	2.3
4	97^o	0^o	2.6

2.2 Observing Strategy

To minimize background residuals, standard 5^o x 5^o grids with the COP[4] move will be used. The grid step size is 2.17^o and the grid axes are inclined by 11.3^o with regard to the instrument axes. The observations are then decomposed as shown in Table 3 such that an

Table 3 CP pointing strategy

Observation	galactic longitude	galactic latitude	Exposure [Ms]	Strategy (1 grid = 5x5 pointings)
1	23^o	0^o	0.3	5 grids, 2400 s/pointing
2	312^o	0^o	0.8	13 grids, 2462 s/pointing
3	60^o	0^o	2.3	38 grids, 2421 s/pointing
4	97^o	0^o	2.6	42 grids, 2476 s/pointing

integer number of grids is achieved. With this strategy and the above given exposure times, the longitude profile of the IBIS exposure map at the end of AO-4 will look as shown in Figure 3 (where AO-4 open time observations have not been taken into account).

[4] *See INTEGRAL Manual on dithering modes*

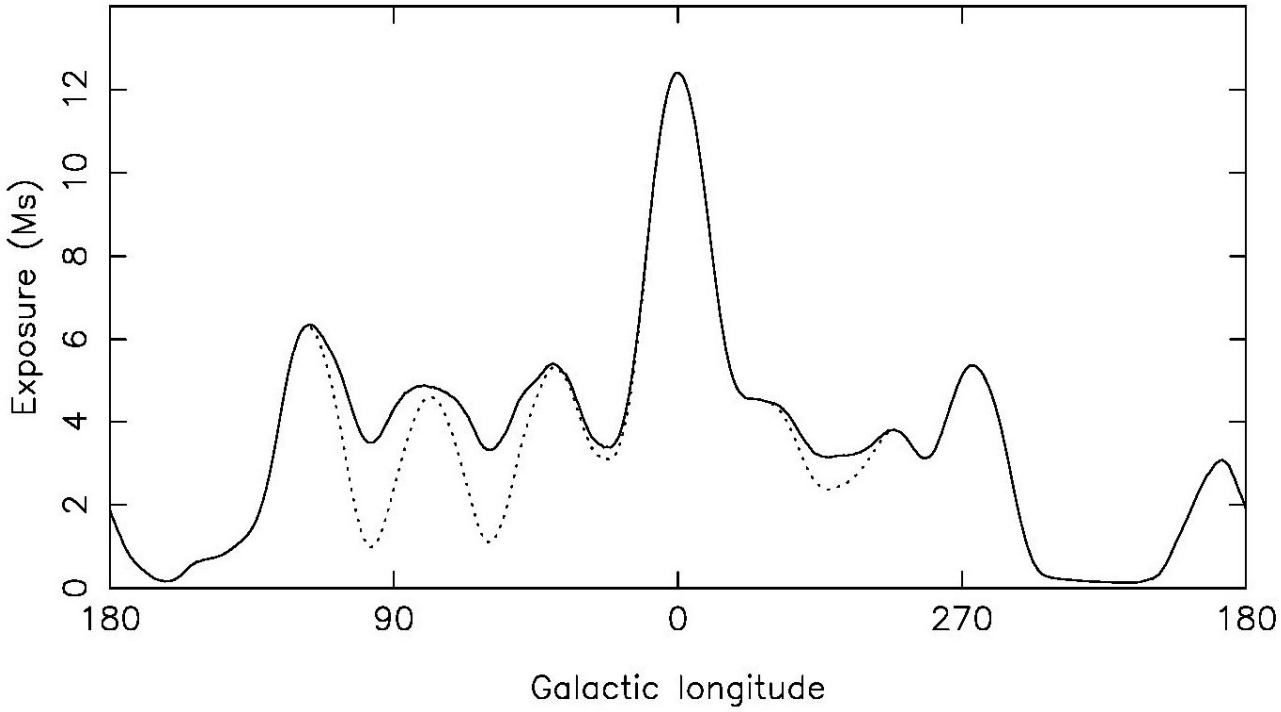

Figure 3 Longitude profile at l=0^o (averaging data from Figure 2 with |b|< 30') by the end of AO-3 (dashed line) and by the end of AO-3 plus CP observations at the end of AO-4 (solid line). Note that open time observations in AO-4, in particular in the Galactic Centre region, will add additional exposure during AO-4.

3 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 *Science Data Rights* and *INTEGRAL Manual*.