INTEGRAL

Science Operations Centre

Announcement of Opportunity for Observing Proposals (AO-6)

AO-6 Key Programmes and Associated Observations

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Table of Contents

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1 Introduction

1.1 INTEGRAL key programmes and associated observations

Proposers considering to submit proposals - in response to this AO - which are to be associated with any of the KP observations approved for AO-6, will find in this document further information for the preparation of their proposals.

Following initial discussions in 2005 within the INTEGRAL Users Group and the INTEGRAL Science Working Team, ESA's Astronomy Working Group has recommended in September 2005 that **"exploitation of INTEGRAL's unique capabilities through key programmes should be encouraged"**. Key Programmes were introduced as a new programme element in 2006.

An INTEGRAL key programme (KP) is a scientific investigation which requires a very significant fraction of the observing time (available per AO cycle) in order to achieve its scientific objectives. A number of selected KP observations will be implemented during the AO-6 cycle of observations (see Section 2). Using the unique "targets multiplicity" feature of INTEGRAL's coded aperture masks, in combination with the very large field of view, allows to simultaneously accommodate the various requirements of the scientific community at large, both for ultra-long KP studies, as well as for observations of other sources contained in the sky area which is covered by the KP observation itself. The latter observations of other sources are identified as observations associated with Key Programmes. These associated observations may focus on individual compact objects (e.g. point sources) which are contained in those large and deep KP fields, requiring usually less observing time, but also for associated observations on specific extended (diffuse) continuum or line emission from a specified area within the KP FOV, and within specific energy intervals, if applicable.

In terms of data rights, the sky area associated with a KP observation is shared by N observers including one PI for the KP and N-1 associated PIs, each having his/her own specific data rights associated with individual sources or areas of diffuse emission. In this context, associated observations can not duplicate the scientific objectives (with source ID's and data rights) of approved KP observations (see Section 2 and Section 4).

The Key Programmes as described in this document are the result of the KP AO-6 Announcement of Opportunity (released in October 2007) which called for new KP proposals to be implemented in this forthcoming AO-6 cycle.

Section 2 provides the reader with a brief summary of the selected KPs for AO-6 cycle of observation. Section 3 describes general guidelines for associated proposals and Section 4 addresses some details on data rights.

2 Overview of Key Programmes for the AO-6 cycle of observations

2.1 Introduction

Following ESA's Announcement of Opportunity for Key Programme (KP) proposals for AO-6 in Fall 2007, the Time Allocation Committee (TAC) has recommended to ESA to implement – during the AO-6 cycle of observations – the following KP proposals. This recommendation has been endorsed by ESA in January 2008.

Proposal ID	Principal Investigator *Affiliation*	Title	Target area	Exposure (ksec)
06K0003	G. Weidens-pointner *MPE, Germany*	Confirming the asymmetry of the positron annihilation radiation from the inner Galactic disk	Inner Galactic disk	2000*
06K0008	T. Maccarone *U Southampton, UK*	Deep observations of 47 Tuc and the SMC	47 Tuc, SMC	2000
06K0012	L. Stella *INAF, Italy*	Giant flares from magnetars in the Virgo cluster	Virgo cluster	2000

Table 1: Key programme proposals selected for the AO-6 cycle of observations.

In addition, the following multi-year KP proposals – initially approved for AO-5 – have been re-approved by TAC for AO-6:

Proposal ID	Principal Investigator *Affiliation*	Title	Target area	Exposure (ksec)
05K0008	G. Bélanger *ESAC, Spain*	Deep INTEGRAL observations of the central molecular zone	Galactic Centre	2000†
05K0010	M. Ajello *MPE, Germany*	The ultra-deep INTEGRAL legacy hard X-ray survey	North Ecliptic Pole	2000†
05K0012	J. Knödlseder *CESR, France*	Nucleosynthesis and anti-matter annihilation in Cygnus X	Cygnus region	2000†

Table 2: Multi-year key programme proposals from AO-5 and re-approved for AO-6.

* Multi-year proposal, another 2000 ksec in AO-7 to be re-confirmed by TAC.
† Multi-year proposal, continuation beyond AO-6 to be re-confirmed by TAC.

The exposure times listed for all proposals in Table 1 and Table 2 are as approved for this AO-6 cycle (one year) only.

In the remaining part of this Section we summarize, per approved KP proposal, the scientific rationale (summary), the observing strategy, and specific data rights allocated to the PI of the KP proposal, so that proposers in response to this AO will be able to submit proposals for targets to be associated with KP pointings (see Section 3).

2.2 Confirming the asymmetry of the positron annihilation radiation from the inner Galactic disk (PI: G. Weidenspointner, 06K0003)

2.2.1 Scientific rationale as provided by proposer (abstract)

For about 30 years we have known that positrons are being born and annihilated in the central region of our Galaxy. The origin of these positrons, however, has remained a mystery. Based on the first 4 years of observations with INTEGRAL/SPI, a very recent publication reported a distinct and totally unexpected asymmetry in the 511 keV line emission emanating from the inner Galactic disk. This asymmetry resembles one in the distribution of hard LMXBs as observed by INTEGRAL/IBIS, indicating that these systems may be the dominant origin of the positrons. If this association is confirmed, it will be the first identification of a specific origin for the positrons (apart from the small fraction which must come from the decay of 26Al). Either way, the asymmetry in the 511 keV line emission signifies a unique characteristic of our Galaxy and gives important clues towards solving a long-standing mystery. INTEGRAL has capabilities uniquely matched to pursuing this problem - capabilities that will not be equaled or surpassed for a very long time. It is crucial to use these to verify the asymmetry in the 511 keV line. To this end, we propose a key programme(which could be spread over multiple observing cycles) that requires in total 4.1 Ms of observation time. This programme is designed to determine the flux difference between two symmetric fields in the inner disk at (l, b) = (± 25˚,0˚) in a robust and largely model independent way by using a special, "beam switching" (chopping) pointing strategy. The two fields are in important regions of the inner Galactic plane that include spiral arm tangents and the 4 kpc dust torus. Our observations can therefore be used via the general observing programme for studies of a large variety and number of steady and transient point sources. Other important INTEGRAL science topics that will benefit from our programme are studies of Galactic disk diffuse line (notably at 1809 keV) and continuum emissions.

2.2.2 Observing strategy

A total of 2 Ms of observing time has been allocated to this KP in AO-6. The observing strategy uses two standard 5x5 dithering patterns with COP[‡] centred on (l, b) = (25˚, 0˚); α_{2000} = $18^h36^m53.70^s$, δ_{2000} = -07º03′19.4″, as well as on (l, b) = (-25˚, 0˚); α_{2000} = $16^h27^m14.74^s$, δ_{2000} = -48º57′19.9″, respectively. The observations of the two regions (taking about 12.5 hours per each 5x5 raster) will be alternated such that each region is observed two times within a single revolution of INTEGRAL. This pointing strategy is designed to minimise systematic uncertainties arising from background variations and allows to determine the difference in the flux between the two fields in a robust way and largely independent of sky and background models. The exposure map resulting from this KP observation is shown in Figure 1 overlaid with contours of exposure time.

[‡] COP = Centre of dither pattern

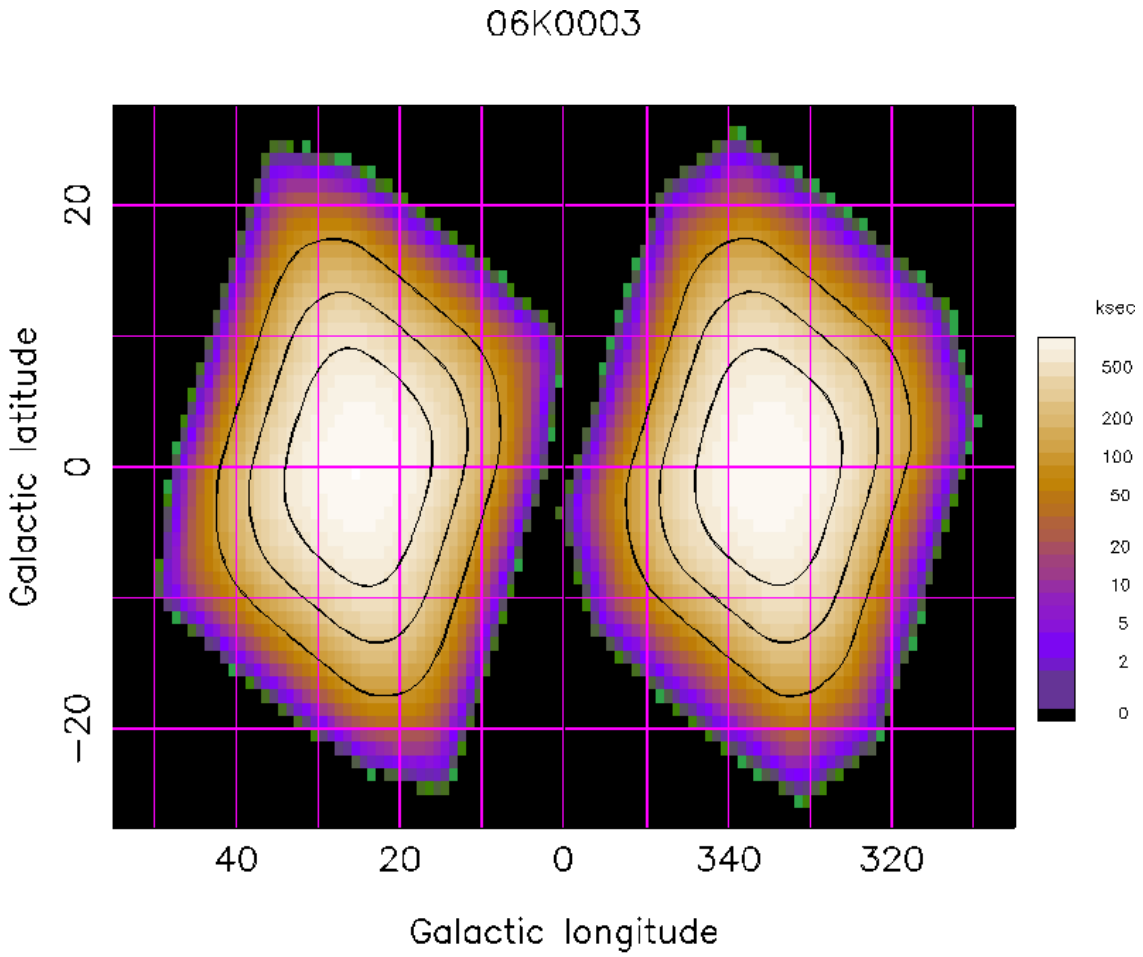

Figure 1: Exposure map (using a total exposure of 2 Ms) for the KP observation ***Confirming the asymmetry of the positron annihilation radiation from the inner Galactic disk (PI: G. Weidenspointner, 06K0003)*** *with contours indicating exposure times of 100, 300, and 600 ks, respectively.*

2.2.3 Data rights

The TAC has allocated the following specific data rights to this KP observation:

Data rights on the positron/electron annihilation line (511 keV) emission. This includes data rights on the ortho-positronium continuum emission.

2.3 Deep observations of 47 Tuc and SMC (PI: T. Maccarone, 06K0008)

2.3.1 Scientific rationale as provided by proposer (abstract)

We propose a 2 Ms INTEGRAL key programme to observe the field containing the globular cluster 47 Tucanae, and the Small Magellanic Cloud. The data will be useful for determining whether there is annihilation line emission at 511 keV from 47 Tuc, and for taking advantage of the wide field of view and good angular resolution of INTEGRAL to make an excellent survey of accretion powered pulsars and allow the first good survey for low mass X-ray binaries and black holes in the Small Magellanic Cloud. If the star formation rate is near the high end of values in the literature, then it should be possible to detect ^{26}Al from the SMC. Finally these data will make for a good survey for active galactic nuclei, due to the high quality radio, optical, and X-ray data in the field, in a region of the sky which has been poorly exposed.

2.3.2 Observing strategy

A total of 2 Ms of observing time has been allocated to this KP in AO-6. The observing strategy uses a standard 5x5 dithering pattern with COP centred on (l, b) = (302.67˚, -44.68˚); α_{2000} = $00^h53^m55.20^s$, δ_{2000} = -72º26′42.0″. The exposure map resulting from this KP observation is shown in Figure 2 overlaid with contours of exposure time.

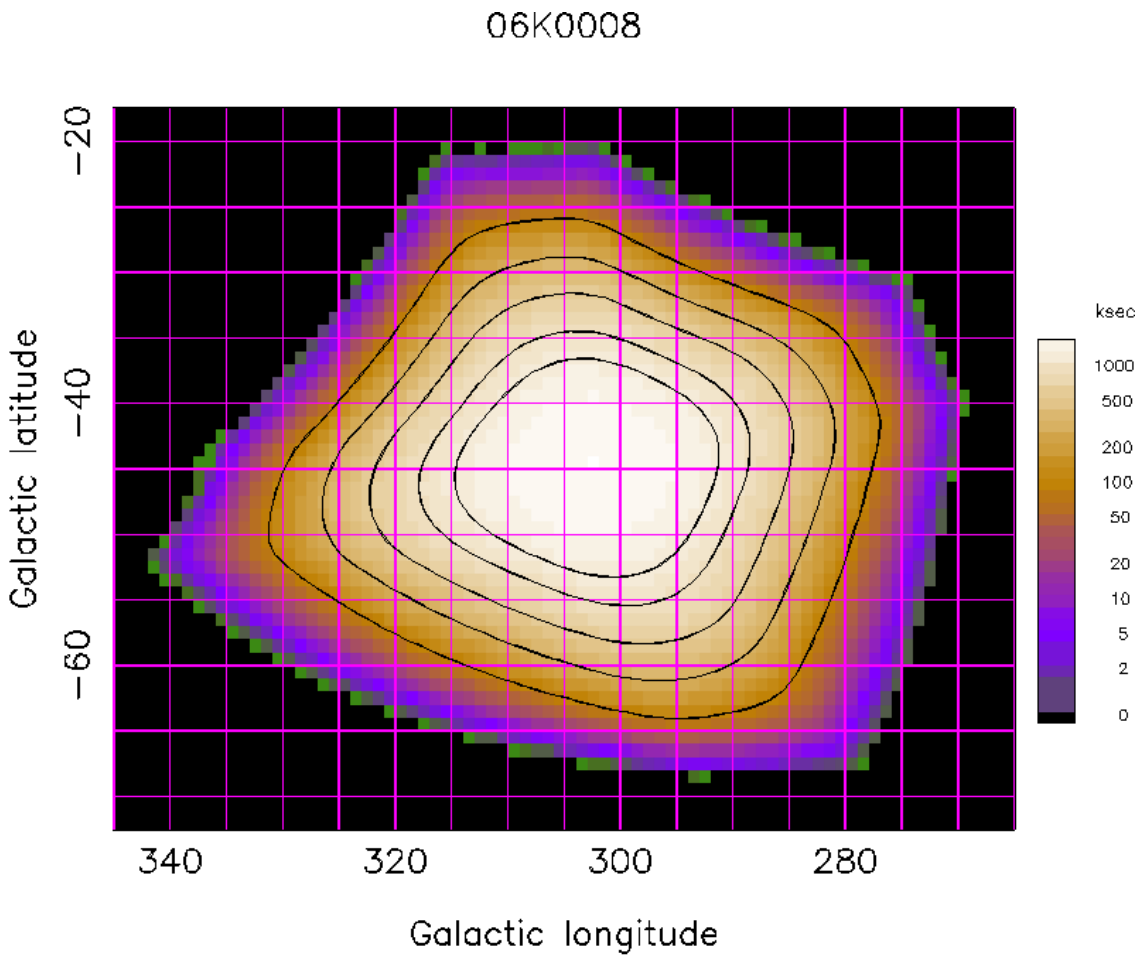

Figure 2: Exposure map (using a total exposure of 2 Ms) for the KP observation ***Deep observations of 47 Tuc and SMC (PI: T. Maccarone, 06K0008)*** *with contours indicating exposure times of 100, 300, 600, 1000 and 1300 ks, respectively.*

2.3.3 Data rights

The TAC has allocated the following specific data rights to this KP observation:

Data rights on the positron/electron annihilation line (511 keV) emission. This includes data rights on the ortho-positronium continuum emission.

2.4 Giant flares from magnetars in the Virgo cluster (PI: L. Stella, 06K0012)

2.4.1 Scientific rationale as provided by proposer (abstract)

Soft Gamma Repeaters (SGRs) likely contain magnetars, neutron stars whose emission is powered by the decay of their exceptionally high magnetic field. These sources emit short duration soft gamma-ray bursts, with a wide range of fluences, the highest being those of the 3 giant flares detected so far. A new perspective in this field was brought about by the 2004 Dec 27 giant flare from SGR 1806-20. The energy liberated in this event was enormous (›› 5×10^{46} erg) and indicates that the internal field of magnetars is ~10^{16} G, i.e. a decade higher than previously thought. Amongst the potentially important consequences of this finding are: (a) newborn fast-spinning magnetars can be powerful sources of gravitational radiation; (b) a sizeable fraction of the short Gamma-Ray Burst population might originate in very powerful giant flares in the local universe; (c) the earth atmosphere damage that a powerful giant flare from a nearby SGR can produce is much higher than previously estimated. INTEGRAL/IBIS is presently the best suited instrument to extend the search for giant flares to a large number of galaxies. We propose here a 2 Ms INTEGRAL observation of the Virgo Cluster, during which 7-13 giant flares are expected to go off. This study should at least double the number of known giant flares, thus yielding much needed information on the recurrence rate and distribution of total emitted energy of these paroxysmal events. The Virgo cluster field has already been shown to be rich in detectable sources and offers an excellent opportunity for further detailed studies. A deep INTEGRAL observation such as that proposed here will afford the study of the high energy emission of 7 known sources, and likely lead to the detection of few serendipitous background AGNs.

2.4.2 Observing strategy

A total of 2 Ms of observing time has been allocated to this KP in AO-6. The observing strategy uses a standard 5x5 dithering pattern with COP centred on (l, b) = (279.67˚, 74.46˚); α_{2000} = $12^h26^m32.10^s$, δ_{2000} = +12º43′24.0″. The exposure map resulting from this KP observation is shown in Figure 3 overlaid with contours of exposure time.

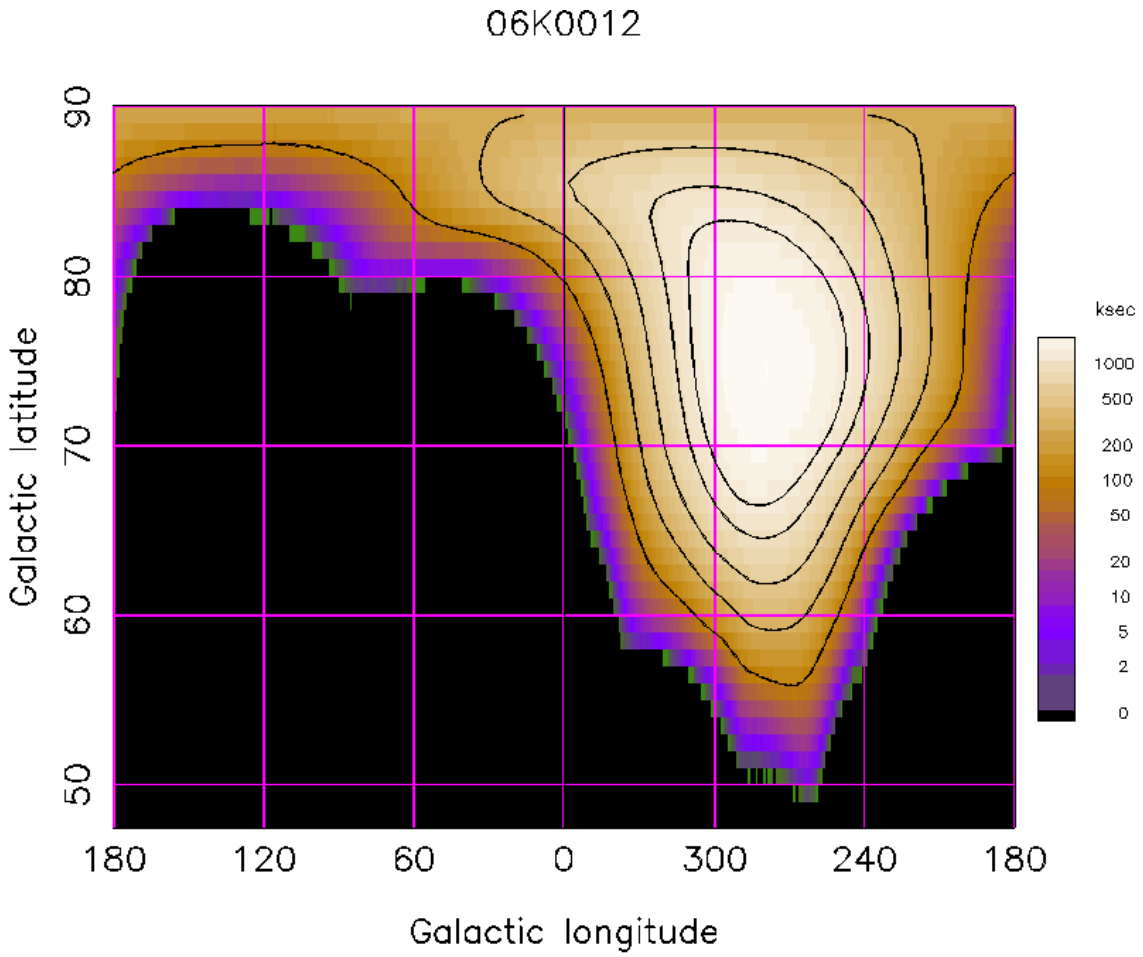

Figure 3: Exposure map (using a total exposure of 2 Ms) for the KP observation ***Giant flares from magnetars in the Virgo cluster (PI: L. Stella, 06K0012)*** *with contours indicating exposure times of 100, 300, 600, 1000 and 1300 ks, respectively.*

2.4.3 Data rights

The TAC has allocated the following specific data rights to this KP observation:

The authors have been granted the right to (i) data from any high energy burst taking place in the direction of the Virgo cluster defined as a sky area of a 8° diameter circular field centred on $\alpha_{2000} = 12^h26^m32.10^s$, $\delta_{2000} = +12°43'24.0"$, *and (ii) to identify putative magnetars and their source properties".*

2.5 Deep INTEGRAL observations of the central molecular zone (PI: G. Bélanger, 05K0008)

2.5.1 Scientific rationale as provided by proposer (abstract)

We underline the importance of deep and continued observations of the central molecular zone (CMZ) of the Galaxy with INTEGRAL, as crucial to gaining a more complete understanding of the origin and nature of the energetic X-rays and gamma-rays detected from this unique part of the Galaxy. We require long cumulative exposure on the CMZ (± 200 pc or ±1.5^{o} from Sgr A*, and request 2 Ms per year for 4 years. We point out that given INTEGRAL's large field of view (FOV), an observation programme in the standard dithering mode for which the nuclear region is the main target, and hence within IBIS fully coded FOV, will satisfy the interests of many, as these central 30^{o} abound in sources of all kinds, including that which is responsible for the intense 511 keV line emission. Our primary interests remain the extended emission from the molecular complexes of the CMZ, including the central, compact emission region known as IGR J17456-2901.

2.5.2 Observing strategy

A total of 2 Ms of observing time has been allocated to this KP in AO-6. The observing strategy is a standard 5x5 dithering observation with COP centred on Sgr A*: $\alpha_{2000} = 17^{h}45^{m}40^{s}$, $\delta_{2000} =$ -29º00′29″, (l, b) = (359º.94, -0º.05)). The exposure map resulting from this KP observation is shown in Figure 4 overlaid with contours of exposure time.

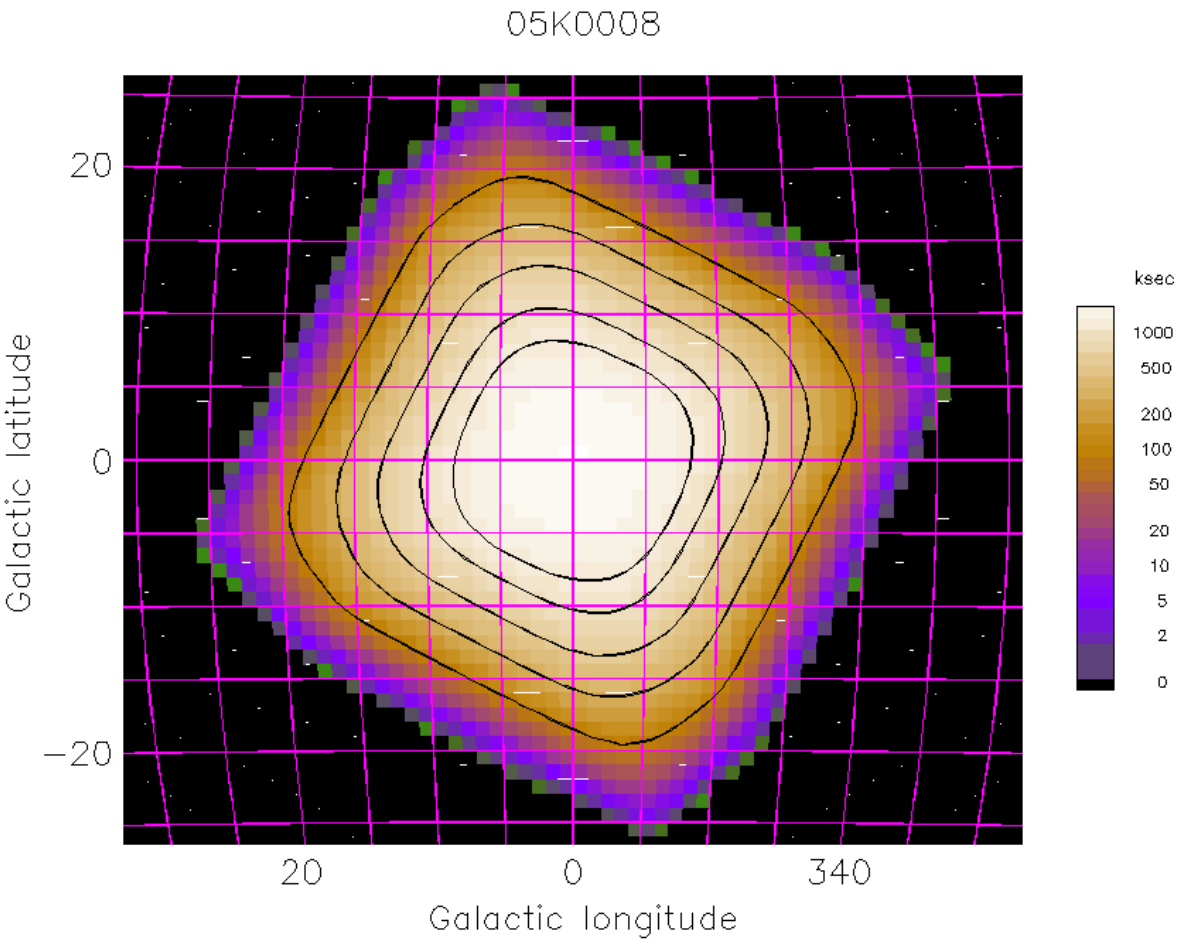

Figure 4: Exposure map (using a total exposure of 2 Ms) for the KP observation ***Deep INTEGRAL observations of the central molecular zone (PI: G. Bélanger, 05K0008)*** *with contours indicating exposure times of 100, 300, 600, 1000 and 1300 ks, respectively.*

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2.5.3 Data rights

The TAC has allocated the following specific data rights to this KP observation:

Extended emission from molecular complexes within the CMZ (3x1 degrees centred on Sgr A), and on the compact emission region known as IGR J17456-2901. These molecular complexes include Sgr B and G0.1-0.1 (aka G0.11-0.11, G0.13-0.13), see* Figure 5.

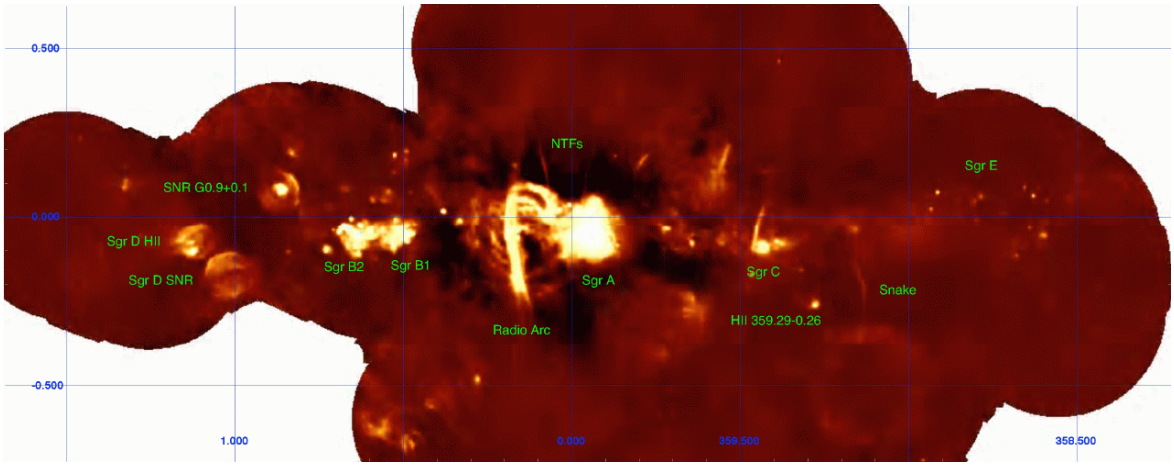

Figure 5: Radio map (20 cm) of the central molecular zone (KP proposal ID = 05K0008), from F. Yusef-Zadeh et al., ApJS, 155, 421, 2005. The coordinate grid is in galactic longitude and latitude (degrees), grid size = 30'.

2.6 The ultra-deep INTEGRAL legacy hard X-ray survey (PI: M. Ajello, 05K0010)

2.6.1 Scientific rationale as provided by proposer (abstract)

A deep observation of the North Ecliptic Pole is proposed. The aim is to reach a factor ~10 lower in flux than achieved previously. A considerable number of new faint sources are expected, which will be used to test the validity of population synthesis models which try to reproduce the X-ray background spectrum. Some of the faint sources will be Compton-thick AGN. The sample of sources will also be used to study the dependence of the obscured-to-unobscured AGN ratio with either redshift and/or luminosity and thus to test the AGN unification model. The good high-energy response of IBIS and SPI will be used to test the presence of a high-energy (>100 keV) cut-off in the AGN spectra of the brightest objects and in the stacked spectrum of all the detected AGN.

2.6.2 Observing strategy

A total of 2 Ms of observing time has been allocated to this KP in AO-6. The observing strategy is a standard 5x5 dithering observation with COP. The coordinates of the central pointing are: $\alpha_{2000} = 18^h00^m00^s$, $\delta_{2000} = +\ 66º33'39''$, (l, b) = (96º.38, 29º.81). The exposure map resulting from this KP observation is shown in Figure 6 overlaid with contours of exposure time.

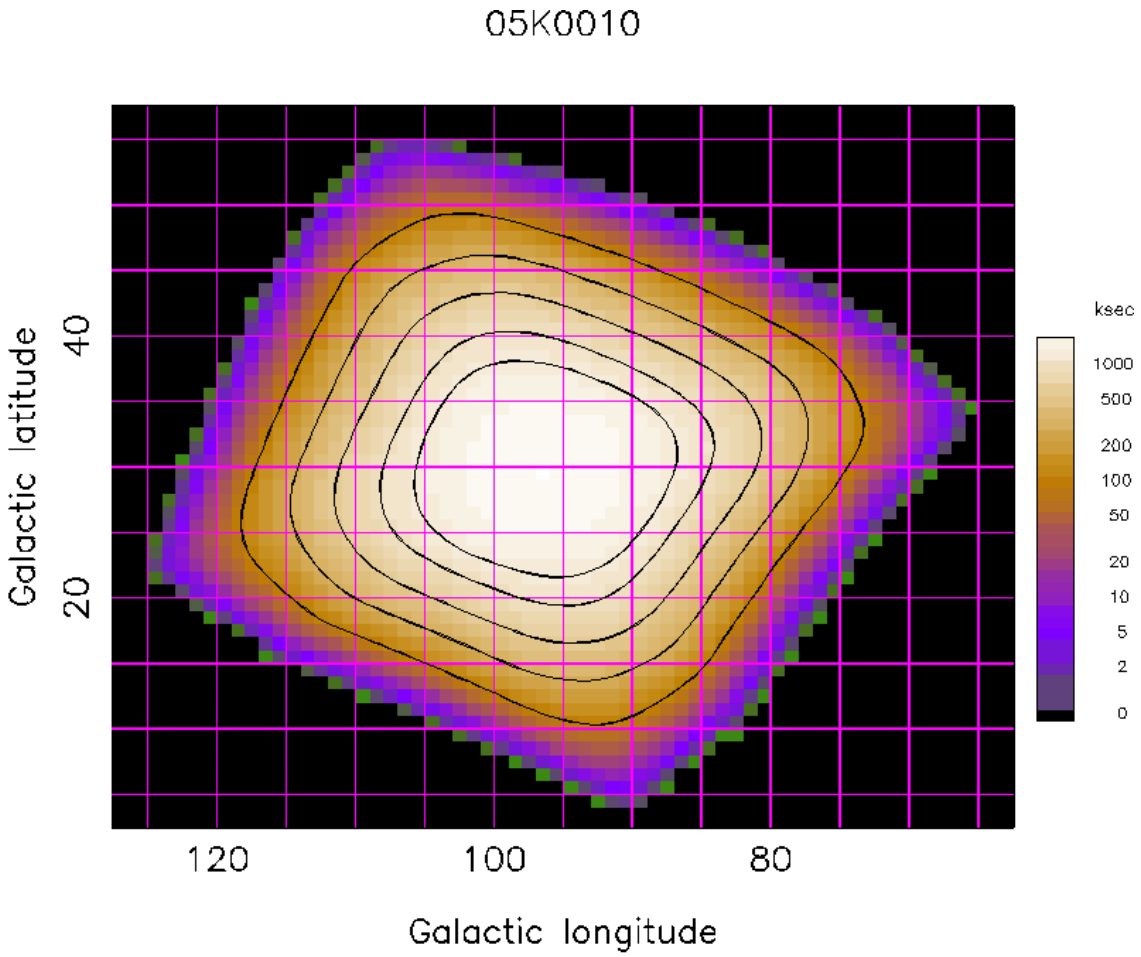

Figure 6: Exposure map (using a total exposure of 2 Ms) for the KP observation ***The ultra-deep INTEGRAL legacy hard X-ray survey (PI: M. Ajello, 05K0010)*** *with contours indicating exposure times of 100, 300, 600, 1000 and 1300 ks, respectively.*

2.6.3 Data rights

The TAC has allocated the following specific data rights to this KP observation:

Data rights granted to allow for a study of the statistical properties of extragalactic objects. The PI has data rights over the source ensemble of such objects detected by INTEGRAL, including new faint (0.1 mCrab) extragalactic sources. This excludes individual sources allocated to other PIs, and any TeV or EGRET sources which are open to all associated PIs.

2.7 Nucleosynthesis and anti-matter annihilation in Cygnus X (PI: J. Knödlseder, 05K0012)

2.7.1 Scientific rationale as provided by proposer (abstract)

We propose a deep 6 Ms exposure of the Cygnus X region as a multi-year INTEGRAL key programme in order to answer a number of central questions related to stellar nucleosynthesis and positron production and diffusion. Cygnus X is the most nearby massive star forming region in our Galaxy, housing several tens of OB associations and massive star clusters at a distance of approximately ~1.5 kpc. The proximity of the region brings gamma-ray line emission from individual star clusters in reach of the SPI telescope and the spatial extent of ~10 degrees of Cygnus X allows to resolve their contributions. The proposed exposure builds on existing observations of roughly ~4.6 Ms of this region. We present analysis results based on the existing observations and illustrate that an additional 6 Ms exposure will allow for a breakthrough in nucleosynthesis and positron annihilation science.

2.7.2 Observing strategy

A total of 2 Ms of observing time has been allocated to this KP in AO-6. The observing strategy will be a 10 x 5 grid, including COP move, centred on $\alpha_{2000} = 20^h35^m53^s$, $\delta_{2000} = +40^o39'49''$, (l, b) = (80º, 0º) using the standard 2.17^o step size between dither points. There will be 10 steps in galactic longitude and 5 steps in galactic latitude. No request is made on the exposure time per grid pointing which will be defined and scheduled by ISOC. The exposure map resulting from this KP observation is shown in Figure 7 overlaid with contours of exposure time.

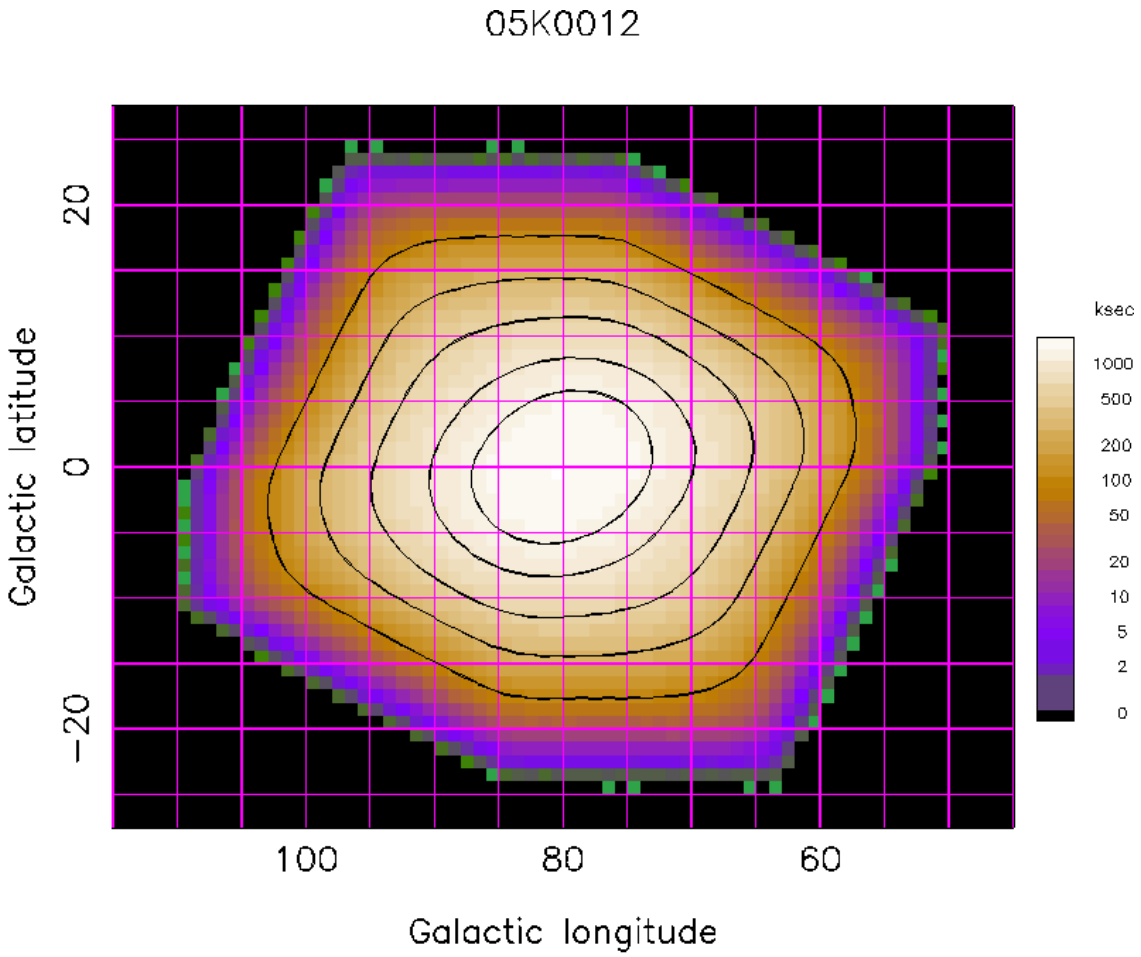

Figure 7: Exposure map (using a total exposure of 2 Ms) for the KP observation ***Nucleosynthesis and anti-matter annihilation in Cygnus X (PI: J. Knödlseder, 05K0012)*** *with contours indicating exposure times of 100, 300, 600, 1000 and 1300 ks ,respectively.*

2.7.3 Data rights

The TAC has allocated the following specific data rights to this KP observation:

Data rights on line emission from ^{26}Al (1.809 MeV), ^{60}Fe (1.173 and 1.332 MeV), and positron/electron annihilation (511 keV) line emission. This includes data rights on the ortho-positronium continuum emission.

3 Proposals for targets associated with the KP pointings

The unique "targets multiplicity" feature of INTEGRAL's coded aperture masks, in combination with the very large field of view, allows to accommodate the various requirements of the scientific community at large. Various targets covered by the FOV of the KP observations can be studied, e.g., long observations on specific extended (diffuse) continuum or line emission regions, possibly within specific energy intervals, but also many individual compact objects (i.e. Galactic and extragalactic point sources) which are contained in those large fields.

Proposers wishing to submit proposals to be associated with any of the KP observations as described in Section 2 should realize that only source locations for point sources and/or extended targets can be proposed provided their locations are within the 100 ksec exposure contour as shown in the various exposure maps of Section 2.

In addition, proposers have to respect the exclusive data rights which have been assigned to the PI's for the KP's (see details provided per KP in Section 2) and which cannot be duplicated, hence, in summary:

1. Locations of sources/areas receiving a KP exposure of 100 ks or more, can be considered ONLY as candidate sources/areas to be proposed in response to this AO and to be evaluated by the TAC.
2. Data rights assigned to PI's of selected KP's need to be observed (see Section 4, and Section 2 for details) and cannot be duplicated.

As is required for all proposals, the exposure required to achieve the scientific objectives has to be justified.

All these proposals will be reviewed by the TAC during the standard AO-6 peer review process, and TAC will assign for successful proposals the data rights on specific source(s), not on the entire FOV, but only per proposal/PI. Concerning un-proposed/non-allocated sources and serendipitous sources in the FOV, we refer to Section 4, and to the AO-6 document on *Science Data Rights*.

A proposal to be associated with the KP may or may not be recommended by TAC to be associated with the KP. If scientifically successful it could also be approved by receiving dedicated exposure time. Likewise, any standard proposal (i.e. disabling the KP flag) may or may not be associated with a KP during the peer review.

3.1 Technical details concerning PGT for associated KP proposals

In this section we provide some technical information about the submission of proposals to be associated with the KP. The user is referred to the PGT section in the *INTEGRAL AO Tools Software User Manual* for further details.

Proposers who are interested to obtain scientific data from KP observations on any target (point or extended diffuse source) as specified in their proposal given the above constraints, i.e. **associated with KP observations,** shall indicate this by enabling the **KP flag** in PGT while submitting their proposals in response to this AO-6 release and providing the information required by PGT. Technically, proposers for these observations have less fields to specify in the corresponding PGT forms. Obviously, the scientific goals to be obtained by the proposed investigation (e.g. required exposure and/or significance of detection) must be compatible with the observing strategies described for KP observations in Section 2.

In the PGT panel "Proposal Details" a checkbox "Key Programme" is available. Once this KP flag is set, the Key Programme to be associated with can be chosen and the following parameters are disabled in the PGT panel "Observation Details":

- Duration (of observation)
- Observation Type
- Dither Pattern including preferred orientation,

as these have been already fixed by the observing strategies implemented for the KP itself and cannot be overwritten.

Likewise, all information containing "Instruments modes" in the same panel are disabled.

Note: It is important to keep in mind that the disabled PGT option "Observation Type" actually implies that sources which are proposed to be associated with a KP observation can only be "observed" as "normal type observation", that is, the submission of proposals including sources which rely on specific TOO criteria and/or fixed time requirements is not possible in this context of KP and associated observations.

Note on proposal ID for KP: IDs for KP proposals which have been submitted and approved by the TAC differ from IDs which have been assigned for them within PGT and the ISOC database for scheduling purpose. A cross-reference is provided in Table 3.

Proposal ID	PI	ID within PGT and ISOC databases
05K0008	G. Bélanger	0630000
05K0010	M. Ajello	0631000
05K0012	J. Knödlseder	0632000
06K0003	G. Weidenspointner	0633000
06K0008	T. Maccarone	0634000
06K0012	L. Stella	0645000

Table 3: Cross-reference proposal ID versus database ID.

4 Data rights

The general policy for AO-6, as outlined in the AO document on *Science Data Rights* is applicable.

The execution of the KP observation, which provides data for the KP-PI, as well as for the approved targets from associated proposals for other PIs can be considered as an "amalgamated" observation from a data-right point of view, and the reader is referred for further details to the section on "Multiple targets in the large instrument FOV, and serendipitous sources" as described in the AO document on *Science Data Rights* for general information on data rights for amalgamated observations.

For a specific KP observation which has been successfully executed so that the scientific data can be exploited, the following should be noted:

[a] All PI's participating in a specific KP observation will receive the entire FOV data for processing and analysis as this is required by the coded aperture characteristics of the instrumentation.

[b] The PI of the KP observation itself (see Table 1, Table 2 and Section 2) has exclusive data rights assigned by TAC on sources/targets as described per accepted KP proposal in Section 2.

[c] PI's for targets to be associated with a KP observation have proprietary data rights on those source(s) or extended area(s) only, which have been approved for them by the TAC. After completion of the TAC process, ISOC will inform all participating PI's about all sources/extended areas which have been allocated by the TAC to individual proposals/PI's. A list of all approved targets will be maintained on the ISOC Web site[§].

[d] All PI's participating in a KP observation, may publish results on any other source or target contained in that KP observation (FOV) which is either not proposed or not allocated by TAC (see item [c]). This rule is, in principle, also applicable for all serendipitous sources located in the area covered by the KP with the exception, however, for data rights on giant flares from magnetars of the Virgo cluster (see Section 2.4).

We draw the attention of the reader to the fact that in previous AOs open time (TOO) proposals on GRB and on outbursts from known SGR were awarded by TAC to open time PIs. Observations of these specific serendipitous sources were in the prime scientific interest of those open time PIs (for GRB and SGR), while they may constitute secondary science objectives only for the PIs participating in the KP. These open time PIs have been granted data rights for a well-specified time interval for these sources (GRB and outbursts from known SGR), even if they occurred inside the KP area during the KP observation. See, however, the specific data rights for KP 06K0012 (L. Stella) in Section 2.4.3 .

In any case, all PIs involved (open time and KP) will be notified by ISOC in due course, after the AO-6 observing programme has been established, about the data rights concerning all observations related to Key Programmes.

[§] http://www.sciops.esa.int/index.php?project=INTEGRAL&page=Target_Lists