THE INTEGRAL CORE OBSERVING PROGRAMME

C. Winkler ¹, N. Gehrels ², N. Lund ³, V. Schönheder ⁴ and P. Ubertini ⁵

(1) ESA/ESTEC, Noordwijk, The Netherlands, (2) NASA/GSFC, Greenbelt, USA, (3) DSRI, Copenhagen, Denmark, (4) MPE, Garching, Germany, (5) IAS, Rome, Italy

ABSTRACT The Core Programme of the INTEGRAL mission is defined as the portion of the scientific programme covering the guaranteed time observations for the INTEGRAL Science Working Team. This paper describes the current status of the Core Programme preparations and summarizes the key elements of the observing programme.

KEYWORDS: INTEGRAL; nucleosynthesis; compact objects; high energy transients.

1. INTRODUCTION

Scientific observing time for the observing programme during the nominal (2 yr) and extended (3 yr) mission phases of INTEGRAL is divided into the open time for the General Observer (General Programme; year 1: 65%, year 2: 70%, year 3+: 75%) and the guaranteed time for the INTEGRAL Science Working Team (ISWT) (Core Programme; year 1: 35%, year 2: 30%, year 3+: 25%). Observing time for the General Programme will be allocated to the scientific community during the AO process. The Core Programme will consist of three elements (see also Gehrels et al. 1997, Ubertini et al. 1997a): (i) Frequent scans of the Galactic plane (Galactic Plane Survey, GPS) (ii) Deep exposure of the Galactic central radian (Galactic Central Radian Deep Exposure, GCDE) (iii) Pointed observations of selected sources. The data from the Core Programme belong to the ISWT for the usual proprietary period of one year, after which the data will become public.

2. SCIENCE OBJECTIVES OF THE CORE PROGRAMME

The scanning of the Galactic plane (GPS) 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] observation). The second reason is to build up time resolved maps of the Galactic plane in continuum and diffuse line emission such as $^{26}\text{Al}$ and $511$ keV with modest exposure. Compton GRO and SIGMA have been detecting Galactic compact 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 rates for events that INTEGRAL can observe is about 2 events/year for
each of these classes, where pointing constraints due to the fixed solar arrays have
been taken 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. The scans will be performed once a week by performing a “slew - and stare”
manoeuvre of the spacecraft along the visible (accessible) part of the Galactic plane
with latitude extent ±10°. The accessible part of the Galactic plane depends on
viewing constraints including the solar aspect angle (40° during first two years, 30°
thereafter) due to the fixed solar arrays, and on the season of the year. The angular
distance between subsequent exposures (965 s each) along the scan path is 6°. The
scan will be performed as a sawtooth with inclination of 21° with respect to the
Galactic plane, each subsequent scan is shifted by 27.5° in galactic longitude.

The deep exposure of the central Galactic radian (GCDE) is driven by the fol-
lowing objectives: mapping line emission from nucleosynthesis radioisotopes (e.g.
$^{26}$Al, $^{44}$Ti, 511 keV), mapping continuum emission of the Galactic ridge, and per-
forming deep imaging and spectroscopic studies of the central region of the Galaxy.
Several interesting emission regions in or near the Galactic plane have been identi-
ﬁed using CGRO OSSE and COMPTEL: these include the $^{26}$Al ($7\times 10^5$ years half
life) mapping the sites of nucleosynthesis in the past million years in the Galaxy
(Diehl et al. 1995), and $^{44}$Ti (half life $\sim 60$ year) which has been detected by COMP-
TEL from the Cas A SNR (Iyudin et al. 1994). 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). Other isotopes such as $^{60}$Fe produce
lines which could be detected 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
$\sim 5°$ and a longitude extent of ±40° (Gehrels & Tueller 1993, Valinia & Marshall
1998, Strong et al. 1999). The exact distribution and spectrum of the ridge emis-
son 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 sours with
arcmin location 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 $\sim 10$ keV and GRANAT/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, Ubertini et al. 1997). 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 are not known. INTEGRAL will study the faintest sources with high angu-
lar 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). The central radian of the Galaxy will be observed using a rectangular pointing grid of $11 \times 31 = 341$ pointings with a pitch of $2^\circ$. The grid covers the celestial region between $-30^\circ \leq l \leq +30^\circ$ and $-10^\circ \leq b \leq +10^\circ$. With 3 minutes slew duration for $2^\circ$ and 1000 s exposure per point, about $4 \times 10^5$ s will be required to scan the grid once. Within the total time allocation for the GCDE, the grid scan will be performed 12 times per year. Remaining Core Programme observing time not spent on GPS and GCDE will be devoted to dedicated pointings on individual sources. These sources include galactic black hole candidates, neutron stars, AGN and some time will also be set aside to be able to perform scientifically important follow-up observations on TOO’s which have been detected during GPS and GCDE or where the trigger has been observed by optical telescopes (SN and Novae). The greatest advantage of INTEGRAL, as compared to other high energy missions, is its high spectral resolution and high sensitivity at energies above 100 keV. The strongest point for INTEGRAL to response to a TOO call is the potential to detect transient high energy emission features (e.g. 511 keV, its scattering feature at 170 keV; 480 keV ($^7$Li); MeV bump; flares from Blazars). The high energy cutoff or spectral break as a function of time may provide critical information to our understanding of the emission mechanism and system parameters. Concerning the high energy continuum, several pointings for each flare or outburst are required to achieve 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. The final list of candidate sources will be published, together with all details of the other Core Programme elements, in the first AO for INTEGRAL observations, which is scheduled for release at the end of 1999. General Observers cannot propose for targets included in the Core Programme list of candidate sources, unless the scientific objectives of their proposals are of a clearly different nature.

The orbit characteristics for INTEGRAL on PROTON (baseline) and ARIANE 5 (backup) are summarised in Winkler (1999) and Carli (1999). The allocation of observing time has been driven by highest scientific priority which has been given to GPS and GCDE and is presently scheduled for the first year of operations (baseline orbit) as follows: GCDE: $4.8 \times 10^6$ s; GPS: $2.3 \times 10^6$ s; Pointed observations: $2.2 \times 10^6$ s assuming an observation efficiency of 85%. It is planned to keep the allocations constant for GCDE and GPS during the year 2 of operations (and for GCDE during year 3 to 5).

3. EXPOSURE TIMES AND SENSITIVITIES

Due to the large coded field-of-views for SPI (FCFOV $16^\circ$ across) and IBIS (FCFOV $9^\circ \times 9^\circ$), a single “staring” point on a GPS scan will not only receive the nominal exposure per pointing (965 s). While this exposure point is still located within the partially coded field-of-view (PCFOV, coverage to zero response), addi-
tional exposure will be collected as the spacecraft (i.e. the co-aligned instruments) is pointing at close neighbouring positions of that single exposure point.

For SPI and IBIS, a single “staring” point will therefore receive ~3000 s of exposure per scan, while JEM-X and OMC – because of the smaller FOV’s – will accumulate 965 s per point/scan. The 3σ sensitivity which can be obtained for one “staring” point during a single scan is therefore 10 mCrab @ 100 keV (IBIS), 750 mCrab @ 1 MeV (SPI) and 6 mCrab @ 10 keV (JEM-X). This will allow detection of transient sources throughout the Galaxy. During the first two years the total exposure per point per year is ~9×10^4 s for SPI and IBIS. For JEM-X and OMC the exposure per point and year amounts to 2.7×10^4 s. The 3σ sensitivity which can be obtained for one “staring” point during a single scan is therefore 10 mCrab @ 100 keV (IBIS), 750 mCrab @ 1 MeV (SPI) and 6 mCrab @ 10 keV (JEM-X). This will allow detection of transient sources throughout the Galaxy. During the first two years the total exposure per point per year is ~9×10^4 s for SPI and IBIS. For JEM-X and OMC the exposure per point and year amounts to 2.7×10^4 s. The area covered by the GCDE will receive a net exposure of 4×10^6 s per year which will give SPI a 3σ sensitivity of ~5×10^-6 ph/(cm^2 s) for narrow lines in the 100 keV - 2 MeV region sufficient for mapping and for detailed line shape studies at 1809 keV (Gehrels & Chen 1996) of the bright 26Al “hot spots” (~3×10^-5 ph/(cm^2 s)) as detected by COMPTEL. The continuum sensitivities (3σ) in the 100 keV to 1 MeV range would be 5×10^-7 to 4×10^-6 ph/(cm^2 s keV) (SPI) and (2 to 1)×10^-7 ph/(cm^2 s keV) (IBIS) while JEM-X would achieve 10^-5 to 10^-6 ph/(cm^2 s keV) in the 3 to 30 keV range. Pointed observations, e.g. nucleosynthesis studies of Cygnus and Vela regions require typically ~10^6 s while Galactic compact (transient) objects could be observed with 10^5 s or less per repeated observation. Given the high sensitivity of INTEGRAL during the GPS (and GCDE), follow-up observations for Galactic TOO’s - like the superluminal jet source GRS 1915+105 or Cyg X–1 - could be triggered if the 100 keV flux would exceed a few hundred mCrab, easily detectable in one GPS exposure. Supernovae and Novae observations would be possibly done repeatedly at various times after onset, to study (e.g. for SNII) early observations of radioactivity from Co breaking through the SN envelope and late observations of 44Ti.

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