INTEGRAL CORE PROGRAM

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ABSTRACT

The INTEGRAL Core Programme is the guaranteed time for the INTEGRAL Science Working Team. This paper gives a progress report on planning activities for the Core Programme and summarizes the preliminary thinking on what kinds of observations will take place during this time.

Keywords: gamma-ray astronomy; future mission; observing program.

1. INTRODUCTION

The INTEGRAL will be an observatory-class mission with 2 years nominal lifetime, possibly extended to 5 years. The observing time will be divided into a General Programme which is open to the scientific community and has observing time selected by a peer review committee and a Core Programme which is guaranteed time for the INTEGRAL Science Working Team (ISWT) and will concentrate on key projects to monitor and map the galactic plane. The percentage of observing time for the Core Programme varies from 35% to 25% as shown in Figure 1.

A subgroup of the ISWT has been formed to begin

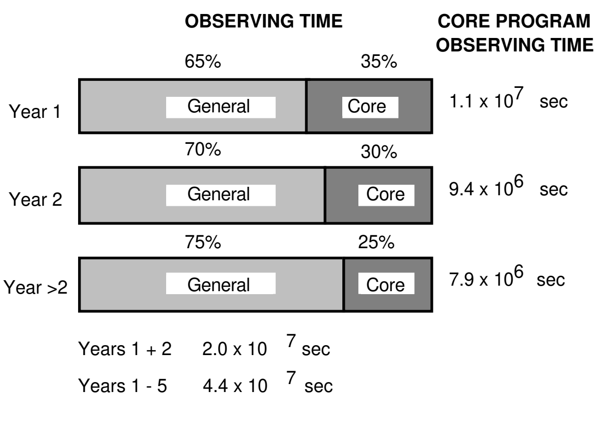

Figure 1. Division of observing time between the General and Core Programmes by years. Also shown is the total amount of core programme observing time available per year and for the sum of the first 2 and first 5 years for the Proton orbit.

studying and planning the Core Programme. It is called the Core Programme Working Group (CPWG) and consists of the authors of this paper. The purpose of publishing this report on the preliminary plans for the Core Programme is to keep the community informed and to solicit comments. If you have comments on the programme, please contact the INTEGRAL Project Scientist, Dr. C. Winkler, at cwinkler@estsa2.estec.esa.nl.

2. CORE PROGRAMME ELEMENTS

The CPWG has tentatively identified three main elements of the Core Programme, namely:

1) Deep survey of the galactic plane in the central radian of the Galaxy.

2) Frequent (approximately weekly) scans of the galactic plane to search for transient sources.

3) Pointed observations of a few selected sources.

These are now discussed in more detail.

2.1. Deep Plane Survey

The scientific objectives of the deep plane survey in the central radian of the Galaxy include mapping line emission from nucleosynthetic radioisotopes, mapping the continuum emission of the galactic ridge and performing deep imaging and spectroscopic studies of the galactic center region.

From the COMPTEL and OSSE instruments on the Compton Gamma Ray Observatory (*Compton*) we know of several interesting gamma-ray line emitters in or near the galactic plane. These include ^{26}Al (half-life = $7{\times}10^5$ years) which maps the sites of nucleosynthesis in the Galaxy over the past millions years (Diehl *et al.* 1995), ^{44}Ti (half-life ~80 years) which has been detected by COMPTEL from the Cas A supernova remnant (Iyudin *et al.* 1994), positron-electron annihilation radiation at 511 keV which is concentrated near the galactic center (Purcell *et al.* 1993; Strong *et al.* 1994) and lines from the interaction of carbon and oxygen nuclei colliding with the interstellar medium in the Orion cloud (Bloemen *et al.* 1994). Other radioisotopes such as ^{60}Fe produce lines that are thought to be detectable by INTEGRAL. The *Compton* discoveries show great promise for gamma-ray line studies, but leave many questions

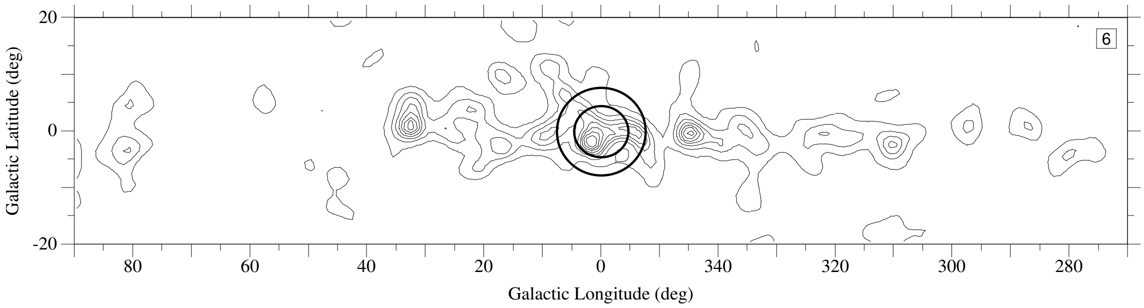

Figure 2. Fully-coded field-of-view for SPI and IBIS (16° and 9°, respectively) superimposed on the COMPTEL map of the 1.809 MeV line emission from ^{26}Al from Diehl et al. (1995).

unanswered. For example, what is the origin of the clumpy structure COMPTEL sees in the ^{26}Al maps? And, can ^{44}Ti emission from undiscovered supernova be found to allow estimates of the supernova rate in the Galaxy? INTEGRAL has the sensitivity to make tremendous progress in these studies. To demonstrate that the fields-of-view of the INTEGRAL spectrometer (SPI) and imager (IBIS) are well suited for galactic plane studies, we show in Figure 2 the SPI field compared to the COMPTEL 1.809 MeV ^{26}Al map in the center radian of the Galaxy. The latitude extent of the emission that COMPTEL detects is well contained in the fully-code portion of the field-of-view.

The INTEGRAL deep plane survey will also study the continuum gamma-ray and hard x-ray emission from the galactic plane. This emission, often referred to as the galactic ridge, is concentrated in a narrow band along the galactic plane with a latitude extent of & 5° and a longitude extend of ±40° (e.g., Gehrels & Tueller 1993). The exact distribution and spectrum of the ridge emission is not well understood. The origin is thought to be bremsstrahlung from cosmic ray electrons, but this is also not fully established. The INTEGRAL will be able to map the emission with high sensitivity and high angular resolution. This will allow the contribution of point sources to be identified and removed so that the distribution and spectrum can be measured with high accuracy.

There will likely be extra time set aside in the deep plane survey to make ultra deep observations of the galactic center. The GRANAT/SIGMA instrument and other earlier experiments have found this region to be filled with variable and transient x-ray and gamma-ray sources (e.g., Cordier *et al.* 1993). Many are thought to be compact objects in binary systems undergoing dynamic accretion. However, the detailed nature of the systems are not known, even for some of the brightest sources in the region such as 1E1740.7-2942 and GRS 1758-258 (e.g., Chen *et al.* 1994). The INTEGRAL will be able to make deep observations with high angular resolution to study even the faint sources in the region. The wide fields-of-view of the instruments will allow all sources in the region to be monitored during each galactic center pointing. Particularly interesting will be searches for gamma-ray emission from Sgr A* at the very center of the Galaxy (Goldwurm *et al.* 1994; Sunyaev *et al.* 1993).

2.2. Frequent Galactic Plane Scans

There are two purposes for scanning the galactic plane. The first and most important is to provide frequent monitoring of the plane for transient sources. The scans would find sources in outburst and then trigger target of opportunity observations if warranted. The second purpose is to build up modest exposure to the entire galactic plane. The preliminary concept is to scan the plane once or twice per week. Each scan will cover only that portion of the plane available to the spacecraft consistent with sun and earth constraints. This amounts to about 160° per scan on average or about 44% of the plane. Over a period of 6 months the entire plane is covered.

Compton and SIGMA have been detecting galactic transients in several different classes, including x-ray novae, superluminal sources (GRS 1915+105 and GRO J1655-40), x-ray binaries (like Cyg X-1) and Be binary pulsars. The occurrence rates for events that INTEGRAL can observe (including pointing constraints) is about 2 per year for each of these classes. The time scales for the transient outbursts vary considerably from class to class and from event to event, but a typical duration is 1-2 weeks and a typical variability time scale is 1 day. This means that scans once or twice per week will allow the transients to be found. There is a trade-off here between more frequent scanning at lower sensitivity that would catch fast transients and less frequent scanning at higher sensitivity that would catch dim transients.

2.3. Pointings at Selected Sources

There are a few sources that may warrant observations in the core program due to their unusual or interesting gamma-ray properties. Examples include the Crab, Cen A, and the Orion cloud.

Table 1. Core Programme Sample Plan

Element	Year 1+2 Time (10^6 s)	Year 1+2 SPI Exposure per field (10^6 s)	Year 1+2 IBIS Exposure per field (10^6 s)
Deep plane survey	10.0	~2.7	~1.5
Galactic plane scans	6.0	~0.27	~0.15
Point sources	4.0	variable	variable

3. OBSERVATION TIMES

The total amount of time available to the Core Programme in the combined first two years is 2.0×10^7 s (see Figure 1). An example of how that might be distributed between the various programme elements listed above is given in Table 1. The exposure per field in the table is a rough number that was estimated assuming uniform scanning along the galactic plane of 60° longitude centered on the galactic center for the deep survey and 360° (i.e., the whole plane averaged over 6 months) for the plane scans. The exposure is simply the Year 1+2 time for each element divided by the number of instrument fully coded fields (SPI FCFOV=16°, IBIS FCFOV=9°) in the longitude range. For example, the SPI exposure for the deep plane survey is 10^7 s / (60°/16°) = 2.7×10^6 s.

For the plane scans, the exposure per field is the total exposure in the first two years. Another number of interest is the exposure per field per scan. Assuming weekly scans and keeping in mind that any given part of the galactic plane is only available to spacecraft about 44% of the time on average, the average number of scans in 2 years for a given portion of the plane is about 46. So the exposure per field per scan is ~5900 s for SPI and ~3300 s for IBIS. For 2 scans per week the exposures would be ~2950 s for SPI and ~1650 s for IBIS.

We note that the deep survey may not be uniform across the central radian of the Galaxy. With special scientific interest in the galactic center, it is quite probable that significantly more time would be spent in that region. For example, $\sim4\times10^6$ s might be spent on the galactic center in the first two years for the Core Programme, leaving about 2.0×10^6 s exposure per field for the rest of the central radian for SPI.

4. SENSITIVITIES

Exposures of 3×10^6 s in the central radian for the deep survey will give SPI a sensitivity for detecting narrow spectral lines of typically 6×10^{-6} ph cm^{-2} s^{-1} in the 100 keV to 10 MeV energy range. For the ^{26}Al line at 1.809 MeV, this kind of sensitivity will allow detailed line shape studies (e.g., Gehrels & Chen 1996) of the bright ($\sim3\times10^{-5}$ ph cm^{-2} s^{-1}) hot spots detected by COMPTEL.

For weekly plane scans, the exposure per field per scan of ~3300 s will give IBIS a ~10 mCrab ($\sim5\times10^{-6}$ ph cm^{-2} s^{-1} keV^{-1} continuum sensitivity at 100 keV. This will allow detection of transient sources throughout the Galaxy.

5. POINTING STRATEGY

The exact pointing strategy for the deep survey and plane scans is under study. It is already clear that the step size along the plane will have to be small, of order 5 degrees, to ensure accurate spacecraft slews.

6. DATA RIGHTS

The Core Programme data rights will belong to the members of the ISWT. This group, which is Chaired by the Project Scientist, is made up of the Principal Investigators of the four instruments, the Principal Investigator of the INTEGRAL Science Data Centre, the Mission Scientist and representatives from the Russian Space Agency and NASA. Most of the data will go to the instrument teams, although the exact division is not fully determined yet. The exclusive rights for the Core Programme data (as for the General Programme data) will last for 1 year after which time the data will become publicly available through the INTEGRAL Science Data Centre in Geneva and/or ESA.

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