Observation of X-ray Novae with INTEGRAL

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Abstract. The INTEGRAL satellite, with the hard X-ray/soft gamma ray telescope IBIS onboard, will be launched in 2001. The core program observations include the Galactic Plane Survey (GPS) and the Galactic Plane Deep Exposure (GCDE). They will respectively provide a weekly coverage of a significant part of the Galactic plane and a deep exposure of the central region of the Galaxy. Both will lead to the discovery of new transient sources, X-ray Novae being the best example. We discuss the possible strategies and results of IBIS/INTEGRAL detection and follow-up observations of X-ray Novae in the framework of the Galactic Plane Survey.

INTRODUCTION

The Imager on Board Integral Satellite (IBIS) [8] is the imaging instrument of the INTEGRAL satellite, the hard-X/soft-gamma ray ESA mission to be launched in 2001. The INTEGRAL observing program is divided in a core program reserved to instrument teams and collaborators and an open observing program. The core program is mainly formed by two kind of galactic surveys: the Galactic Plane Deep Exposure and the Galactic Plane Survey (GPS) [11]. The first one will consist of deep pointings of the central region of the Galaxy. The GPS (for a total of 2.3 10^6 s per year) instead is composed of a series of separate short pointings arranged to perform a scan of a section of the galactic plane every week.
This portion of the core program will monitor the galactic plane to search for galactic transient sources at the beginning of their outbursts. The discovery and arcminute positioning of a new transient source will trigger INTEGRAL TOO observations, and will generate an alert to the astronomical community enabling ground and space observatories to start observations at different wavelengths. If a TOO observation is not triggered, the GPS will anyway follow the transient during its outburst with an observation every week, if the pointing constraints allow it. We present here (but see also [2]) simulations of IBIS Galactic plane survey observations. They show the capabilities of this instrument in discriminating between different sources while at the same time monitoring a huge FOV. Prime target of the INTEGRAL GPS program in particular with the IBIS telescope are

X-Ray Novae [7,1] a class of hard X-ray transients known to contain black holes accreting matter from a low mass companion star.

THE IBIS TELESCOPE

IBIS provides diagnostic capabilities of fine imaging, source identification and spectral sensitivity to both continuum and broad lines over a broad (15 keV–10 MeV) energy range. It has a continuum sensitivity of 4 10^{-7} ph cm^{-2} s^{-1} (1 mCrab) at 100 keV and 2 10^{-7} ph cm^{-2} s^{-1} (25 mCrab) at 1 MeV for a 10^6 seconds observation (ΔE=E) and a spectral resolution better than 7 % at 100 keV and of 6 % at 1 MeV. The imaging capabilities of the IBIS are characterized by a 12$'$ FWHM angular resolution, a 3$'$ to $<$1$'$ point-source location accuracy and a very wide field of view (FOV), namely 9° × 9° fully coded and 29° × 29° partially coded at 0 sensitivity.

The IBIS detection system is composed of two planes, an upper layer made of 16384 squared CdTe pixels (ISGRI) and a lower layer made of 4096 CsI scintillation bars (PiCsIT). This system enables high sensitivity continuum spectroscopy and a wide spectral range (15 keV – 10 MeV).

The simulation we performed are for the moment limited to the ISGRI upper layer [6]. The ISGRI pixels are 4× 4 mm^2, 2 mm thick crystals of Cadmium Telluride, a semiconductor operating at ambient temperature, providing a spectral resolution of about 8% at room temperature. The 128×128 pixels are arranged in 8 modules separated by dead zones 2 pixel wide needed by the mechanical structures which sustain the detector plane. The sensitivity loss caused by dead zones is not large, however the absence of sensitive elements in the detector plane must be properly taken into account during deconvolution procedures [5].

GPS PARAMETERS AND SIMULATIONS

One GPS scan will involve 18 to 57 (depending on visibility and satellite constraints) 1050 sec pointings spaced by 6° on a saw-tooth pattern inclined by 21° with respect to the galactic plane [11]. This effectively results in an coverage of regions extending from 100° up to 320° in Galactic Longitude and 40° in Galactic Latitude. Every week the scan is repeated with a 27° shift in longitude. Taking into account the scan pointings and the sensitivity over the FOV, the effective IBIS exposure for each sky point along the path is about 3250 seconds, which translates in a 3σ sensitivity of ∼20 mCrab in the 50-150 keV band. This is vastly better than the sensitivity level of the BATSE occultation analysis on similar timescales, assuring the monitoring of hard X-ray sources activity at a level never reached by past all-sky monitors.

We simulated a GPS scan in the 50-150 KeV band containing 2 galactic regions from -30° to 60° and from 90° to 180° in longitude. We selected a sample of hard X-ray galactic sources extracted from the Heasarc X-ray binaries catalog [9] and containing the sources monitored by BATSE in its occultation program

TABLE 1. Sources, their simulated 50-150 keV flux and measured signal to noise level at source position (level of detection for Novae).

GRS 1716-249	100 mCrab	16 σ	Bright Nova	1 Crab	170 σ
SLX 1735-269	90 mCrab	16 σ	4U 1630-472	100 mCrab	10 σ
GX 1+4	40 mCrab	7 σ	GX 339-4	200 mCrab	22σ
GRS 1758-258	60 mCrab	13 σ	OAO 1657-415	100 mCrab	13 σ
GS 1826-38	30 mCrab	2.6 σ	GRO J1655-40	200 mCrab	27 σ
GS 1845-03	100 mCrab	21 σ	4U 1700-377	250 mCrab	38 σ
A 1845-024	40 mCrab	8 σ	GX 354-00	50 mCrab	8 σ
GRS 1915+105	300 mCrab	51 σ	Faint Nova	30 mCrab	6 σ
QSO 0241+622	100 mCrab	20 σ	1E1740.7-2942	100 mCrab	18 σ
LSI+61 303	20 mCrab	2.5 σ	A 1742-294	20 mCrab	2.5 σ
4U0115+63	50 mCrab	8 σ	Terzan 2	30 mCrab	5 σ

(http://cossc.gsfc.nasa.gov/cossc/batse/ hilev/occ.html) and transient and persistent sources detected by the SIGMA hard X-ray/soft γ-ray telescope in the Galactic plane [4]. The sample was selected in order to give a representative example of GPS results and possibilities but we consider that several other sources could be detected in an average scan, especially at lower energies. The simulated fluxes are representative of the average behaviour of these sources. To this sample we added two serendipitous transient events to check the sensitivity of our procedures to these occurrences. A bright (1 Crab) one to test the localization capability of our system and a faint (25 mCrab) one in a crowded region to test the source discrimination capability. We simulated the bright one in the second scan (l between 90° and 180°) while the faint transient in the Galactic Bulge, where most of the weak X-ray novae like GRS 1739-278 [10] were observed.

The simulated images are deconvolved, analysed, cleaned and summed [5]. In this process point-sources are detected and localized by fitting with the proper Point Spread Function. A section of the resulting image of the first scan (around the Galactic Center) is displayed in Fig. 1. The simulation parameters and the deconvolution results are shown in Table 1. Note that the signal to noise level depends both on source strength and on its effective exposure. The GPS sensitivity is maximal (RMS noise 6 mCrab) on the galactic plane and decreases towards the image limits. From the results reported in Table 1 it is clear that hard X-ray sources will be easily detected if they have a flux $\geq$ 30 mCrab.

We here focus on IBIS capability of positioning a new source in the two cases we simulated. The 1 Crab transient can be positioned by IBIS in principle with a 90% error radius of <10 arcseconds. In reality some systematic effects (e.g due to thermal distorsions) are expected to limit the accuracy to $\sim$20$''$ (but proper in-flight calibrations and modelling should allow to correct part of these effects

after the first months of the mission). This gives reasonable possibility of promptly identifiying the optical/radio counterpart from the ground directly from the IBIS derived position.
The 30 mCrab transient is easily detected in a crowded region at a 6 σ level (see detailed image in [2]) with a $2'$ error radius, a value comparable to the one obtained by XTE/PCA for stronger ($\sim$200 mCrab) transients like XTEJ1755-324. On the other hand this error box is too big to allow a direct identification from the ground. An optical/radio search of the counterpart may however be pursued from the ground trying to identify highly variable objects in the error box. Follow up observations with more sensitive X-ray instruments will in principle allow to identify the origin of the emission. If the object is an X-ray Nova at its maximum [10], then it is likely located on the other side of the Galaxy allowing us to probe this largely unknown region.

CONCLUSIONS

We have presented simulations of IBIS/INTEGRAL GPS observations, the main result are the following:
1) Several known sources will be clearly ($\geq$ 10 σ) detected allowing to determine their spectral state.
2) Bright transient sources will be readily localised with a precision previously unavailable in this energy range. The high level of detection will allow to search for high energy features [3] and other spectral signatures of BHs in X-ray Novae.
3) Fainter, more distant transients will be detected and localised with lower precision allowing to determine the number of these sources in the Galaxy.

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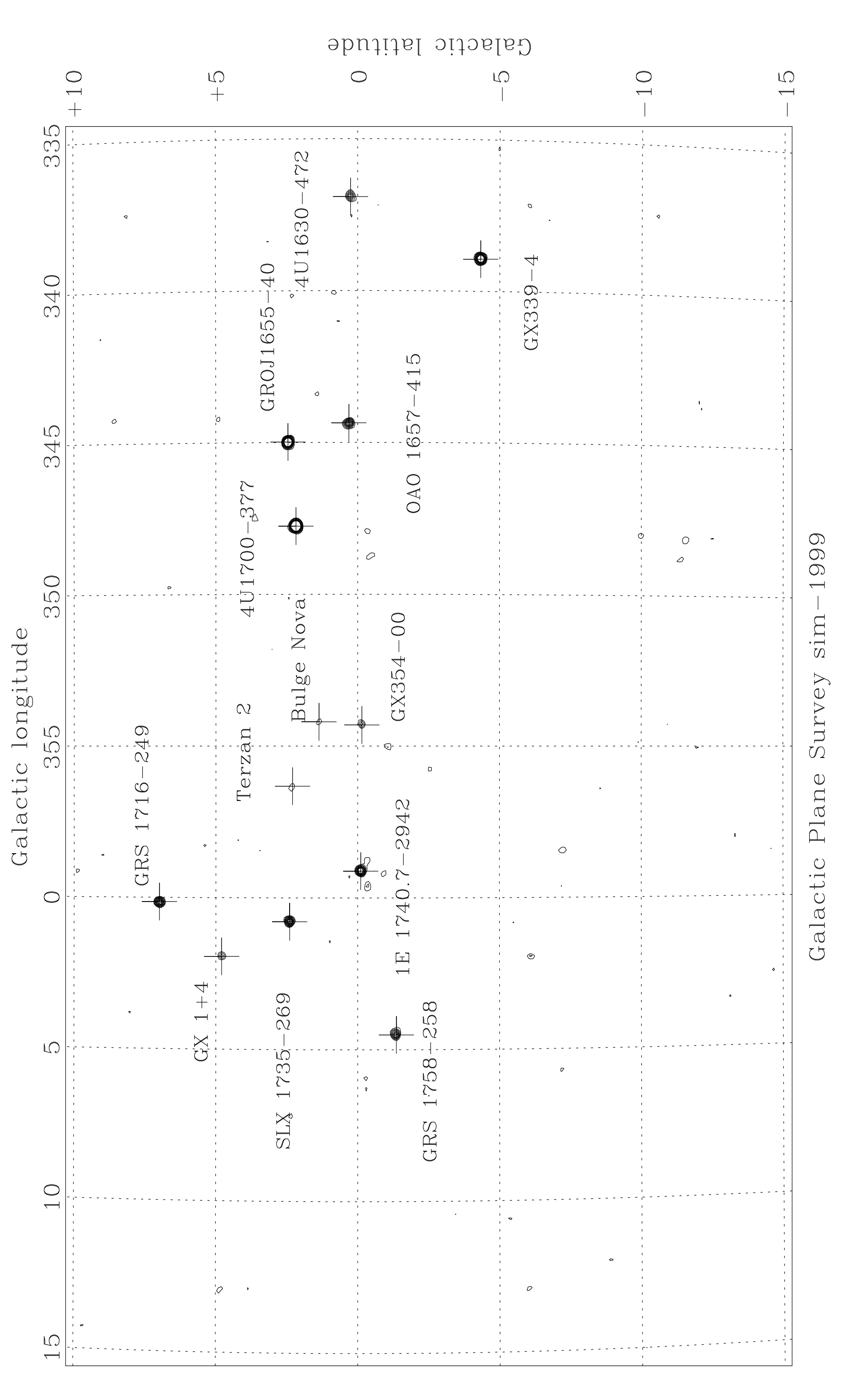

FIGURE 1. Contour level image of part of the 50-150 keV reconstructed sky region of a simulated GPS scan with the IBIS telescope. Levels start from 2.5 σ, spaced by 1 σ. All marked sources are detected at more then 4.5σ