SPI imaging prospects for diffuse Galactic continuum hard X-rays.

A.W. Strong[1], R. Diehl[1], P. Connell[2], G.K. Skinner[2]

1) Max-Planck-Institut für extraterrestrische Physik, D-85740 Garching, Germany
2) University of Birmingham, School of Physics and Space Research, Birmingham B15 2TT, U.K.

ABSTRACT The performance of the INTEGRAL Spectrometer SPI for large-scale imaging of the Galactic diffuse continuum emission has been studied. Simulations of long-term survey data have been made based on the computed SPI response and background estimates for Galactic emission based on OSSE results. Since for continuum emission the background in a wide energy band is much larger than for narrow lines such as 511 keV or ^{26}Al, the background is larger; however this is compensated by the higher intensity of the Galactic continuum. Expected results for the 200 - 400 keV band are presented.

KEYWORDS: gamma rays; INTEGRAL ; data analysis; image reconstruction; diffusion.

1. INTRODUCTION

The spectrometer SPI on INTEGRAL (Mandrou et al. 1996) has as its main goal imaging the sky in the domain from hard X-rays up to gamma-rays of several MeV. While high spectral resolution is required to separate different astrophysical source processes in this regime, it is essential for the astrophysical interpretation to extract spatial information though imaging analysis. SPI is designed to enable degree-scale imaging, motivated by the dominating diffuse source processes in this energy range: OSSE, COMPTEL, GINGA, and RXTE have established hard-X/low-energy gamma-ray continuum emission from the Galaxy. OSSE on GRO has shown that the Galactic plane is an intense source of hard X-ray emission in the 50-500 keV range, and this has been extended to lower energies by GINGA (Fig 1). The origin of this emission is unknown but may be the combined emission from many point sources such as supernova remnants.

Instrumental background in SPI is expected to be large, dominating the sensitivity. Most of this background arises from radioactivity generated within the instrument (Jean et al. 1996). However the Ge detectors themselves can be used to suppress part of this background, especially at higher energies, through analysis of the detector signal pulse shapes. Pulse-shape discrimination (PSD) is used above 200 keV to reject β-decay background in the Ge detectors (Slassi-Sennou et al. 1996), and the resulting background increases only slowly to low energies (Fig 2), while the Galactic emission has roughly an E^{-2} spectrum, so the signal-to-noise for continuum emission improves rapidly below 1 MeV.

There remains considerable background above about 1 MeV, and at low energies below 200 keV the pulse shape suppression fails, resulting in a much higher background level there. The most significant imaging results from SPI should therefore be expected in the gamma-ray lines, and in the continuum at low energies just above the pulse shape suppression threshold.

2. EXPECTED PERFORMANCE

We study the expected performance in the 200-400 keV band; the model is based on the OSSE intensities with a Gaussian distribution with $\sigma = 20^o$ in longitude and 2^o in latitude. The analysis uses a current representation of the SPI response based on ray-tracing and Monte-Carlo simulations of the instrument. The data are simulated using the response combined with background based on Fig 2. The background in each of the 19 detectors is assigned an independent value, and these background values are reconstructed during the fitting procedure. Handling time-variable background is not included here although this is also foreseen. The images are made with the maximum-entropy method (MEMSYS5 system), fitting the image and the background simultaneously. The error bars on the profiles are computed from the posterior probability function using the utility provided in MEMSYS5.

Fig 3 (left) shows what could be expected in about 4 months of the Galactic Centre Deep Exposure (GCDE). This is a core programme monthly scan of $-30^o < l < 30^o$, $-10^o < b < 10^o$ a $2^o \times 2^o$ grid with 1000s per pointing, so that after 4 months we expect the equivalent of 4000s per pointing. The image shows clearly the Galactic plane, but with some artefacts due to the limited latitude coverage. When the latitude range is exended to $-20^o < b < 20^o$ on a $4^o \times 4^o$ grid with the same exposure per pointing, the image is much improved and matches well the model distribution (Fig 3 right).

Fig 4 illustrates evaluation of the same cases using a constrained linear matrix reconstruction technique. An improvement is again seen when the latitude coverage is extended, indicating that this effect is not a result of the imaging method but is related to the information present in the off-axis exposures.

3. CONCLUSIONS

SPI is expected to give good quality images of the diffuse continuum hard X-ray emission from the Galactic plane. However the survey pointing strategy has to be carefully optimized in order to obtain best results.

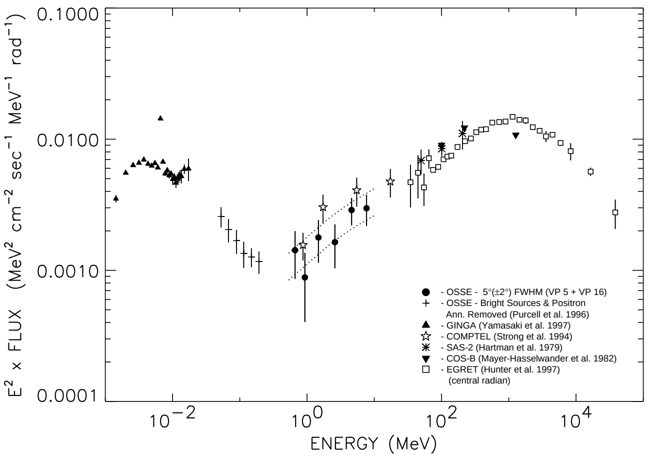

FIGURE 1. Spectrum of inner Galaxy as given by Kinzer et al. (1997).

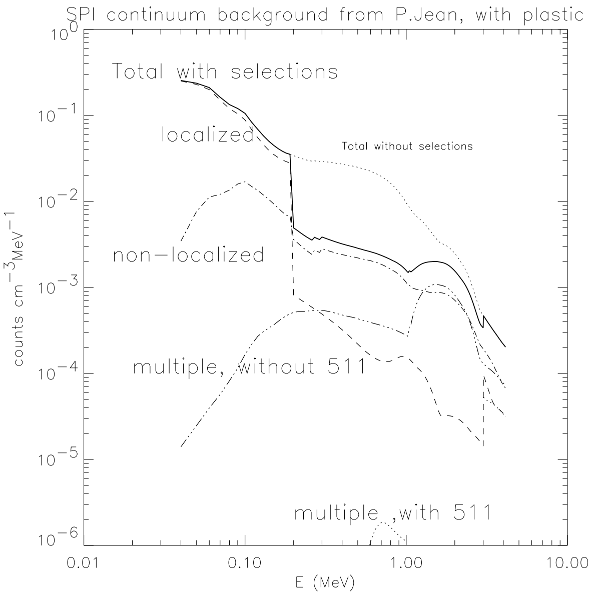

FIGURE 2. Spectrum of SPI background (Jean et al. 1996 and private communication)

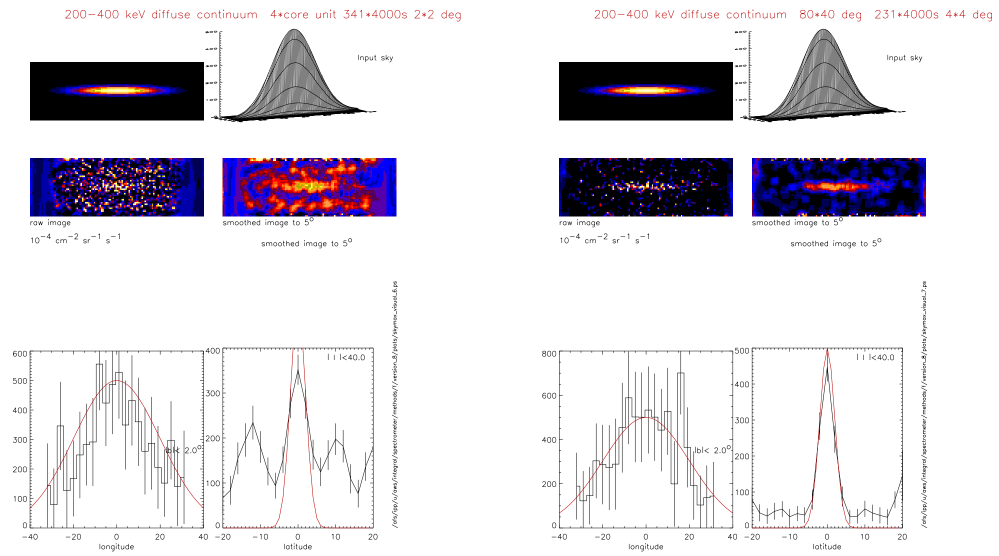

FIGURE 3. Left: Original image and reconstruction for scan of $-30^o < l < 30^o$, $-10^o < b < 10^o$ on a $2^o \times 2^o$ grid with 4000s per pointing. Right: Same for scan of $-40^o < l < 40^o$, $-20^o < b < 20^o$ on a $4^o \times 4^o$ grid. In both sets the plots are, from top to bottom: original image as colour and surface plot, raw and smoothed (by 5^o) reconstruction, reconstructed longitude and latitude profiles (error bars) compared to original profile (red lines).

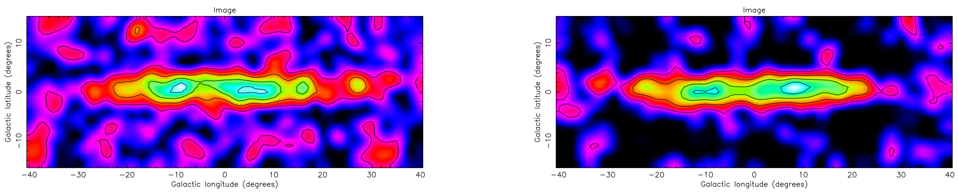

FIGURE 4. Constrained linear matrix reconstructions for the same models and observations as in Fig 3.

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