COMPTEL skymapping: a new approach using parallel computing.

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ABSTRACT Large-scale skymapping with COMPTEL using the full survey database presents challenging problems on account of the complex response and time-variable background. A new approach which attempts to address some of these problems is described, in which the information about each observation is preserved throughout the analysis. In this method, a maximum-entropy algorithm is used to determine image and background simultaneously. Because of the extreme computing requirements, the method has been implemented on a parallel computer, which brings large gains since the response computation is fully parallelizable. The zero level is left undetermined in this method. Results using data from 7 years of COMPTEL data are presented.

KEYWORDS: gamma rays; COMPTEL; data analysis ; surveys.

1. INTRODUCTION

The goal of this work is to produce quantitatively correct intensity maps which are free from astrophysical biases, in order to explore unknown emission in the MeV regime from COMPTEL. The high instrumental background level of COMPTEL implies that imaging methods require a good estimate of the background. In the absence of an independent ('off') measurement for our case of continuum (as opposed to spectral-line) emission, one approach is to use high-latitude observations, where essentially only the instrumental and cosmic diffuse backgrounds are present, as a template for the background model. The assumption that the background in the instrumental system has a constant form in at least the spatial coordinates (but not in Compton scatter angle) may serve as the basis for an imaging method. The idea is to construct skymaps using all observations simultaneously and explicitly, preserving the instrument-system for the dataspace and preserving the specific information for each observation. Since COMPTEL has more than 240 observations covering the whole sky this procedure requires very large CPU resources. This is the reason why such an approach had to await the feasibility of parallel computing

2. METHOD

It is assumed that the COMPTEL response for one observation i to an intensity distribution I_γ has the usual form in terms of the expected counts n_i :

$$n_i(\chi,\psi,\overline{\varphi}) = g_i(\chi,\psi,\overline{\varphi}) \int\int I_\gamma(\chi',\psi')X_i(\chi',\psi')f(\chi',\psi',\chi,\psi,\overline{\varphi})d\Omega + B_i(\chi,\psi,\overline{\varphi})$$

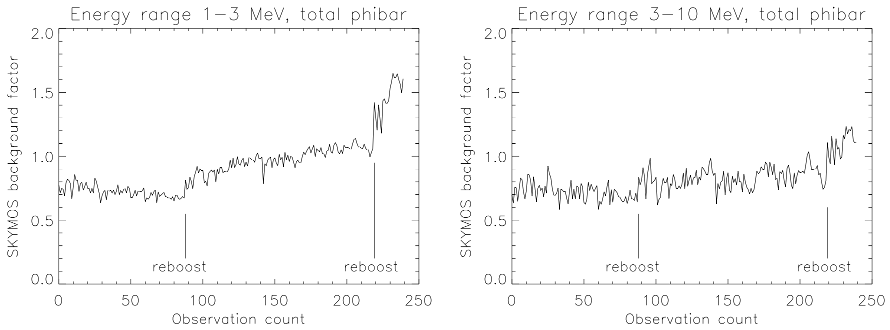

FIGURE 1. Relative background estimate as function of time for 1-3 and 3-10 MeV.

where χ, ψ are the spherical coordinates of the scattered photon direction, $\overline{\varphi}$ is the Compton scatter angle, g_i are the geometrical factors , X_i is the exposure and f is the point-spread function, Ω is the solid angle. $B_i(\chi, \psi, \overline{\varphi})$ is the instrumental background of the observation. The dataspace of observations consists of all the n_i and the response is all the X_i and g_i. The background is represented as $B_i(\chi, \psi, \overline{\varphi}) = B_o(\chi, \psi, \overline{\varphi})b_i(\overline{\varphi})$ where B_o is a template derived for example from many high-latitude observations, and b_i is the scaling factor for the observation i for each $\overline{\varphi}$. The b_i are treated as free parameters to be determined, so that finally we only use the (χ, ψ)-distribution of the template. The b_i thus include both temporal and $\overline{\varphi}$ variations of the background, and give $\mathrm{n}_{\overline{\varphi}}$ parameters per observation. However for cases where the $\overline{\varphi}$-distribution is known to be stable (for example above 10 MeV) it can optionally be taken from the template, so that only temporal variations are considered, with only one parameter per observation. The time-dependence of the background is a by-product of the method which can be compared with other determinations. Using high latitude observations the template is generated using $B_o = \frac{\Sigma n_i(\chi,\psi,\overline{\varphi})}{\Sigma g_i(\chi,\psi,\overline{\varphi})\overline{X_i}}$. Since n_i and g_i are always in the instrument system they are aligned for all observations, so that no interpolation is required. The present imaging method is differential so that the zero level of the maps is undetermined.

The parallelizing technique is to assign one PE (processing element) to each observation, and to run the code simultaneously on all PEs. Upon reaching the convolution part of the calculation each PE computes only the response for its assigned observation; the result is then transmitted to all other PEs so that each obtains the full response as required for the imaging. In this way the 'acceleration factor' is practically equal to the number of PEs. For full-sky images one convolution requires about 5 minutes CPU on a Cray T3E, and one iteration requires about 10 convolutions. This gives about 1 iteration per CPU hour. Since the aim is to obtain intensity maps which can be used quantitatively, the iterations were continued until saturation in intensity was reached. The effect of this is also to produce overstructured maps on small scales so that a smoothing was applied before plotting.

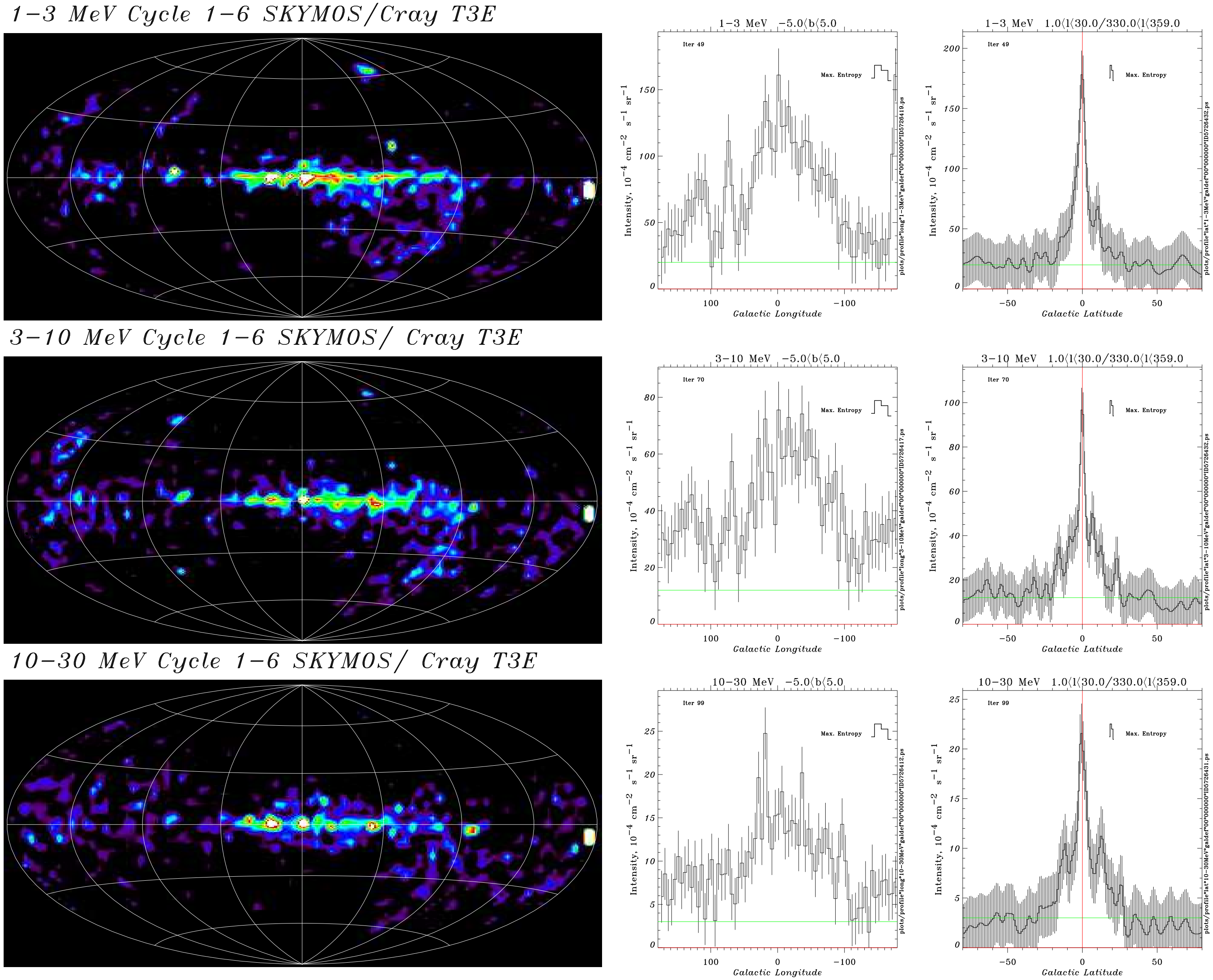

FIGURE 2: Full sky intensity maps and longitude, latitude profiles for 1-3, 3-10 and 10-30 MeV. Green lines in profiles indicate *approximate* base-level.

3. RESULTS

The method was applied to all 240 observations from Cycles 1-6, for 1-3, 3-10 and 10-30 MeV. Fig 1 shows the derived variation of background with time, relative to the average high-latitude value. The increase due to reboosts is visible, as expected. The temporal behaviour agrees with detailed activation background histories derived from spectral analysis of identified background features (Varendorff et al. 1997). Fig 2 shows skymaps and longitude, latitude profiles. The skymaps have been smoothed over 5^o wide bins. The longitude profiles are for $|b| < 5^o$ with 5^o longitude bins, the latitude profiles are for $330^o < l < 30^o$ with 1^o latitude bins. The error bars are estimated from the fluctuations in the maps at high latitudes where little structure is expected. The zero level of the sky intensity is not determined in this method, so these plots have an arbitrary baseline. A representative high-latitude level is indicated, but note that this is not unique.

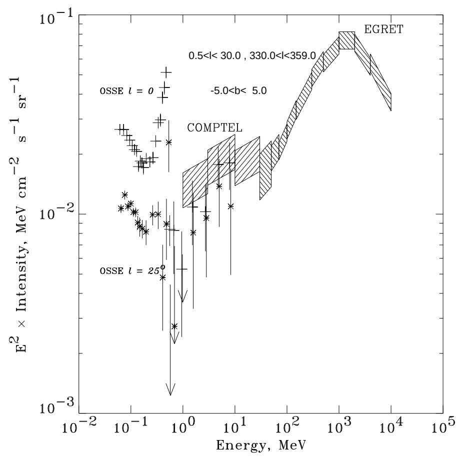

FIGURE 3.
Spectra of inner Galactic plane
$330^o < l < 30^o$ $|b| < 5^o$.

COMPTEL: this work

EGRET spectrum based on
Strong and Mattox (1996)

OSSE spectra from Kinzer et al. (1997)

Figure 3 shows the spectrum of the inner Galactic plane for $|b| < 5^o$ based on these maps, using the high-latitude intensity as baseline. It is higher by about a factor 2 than given in Strong et al. (1997), which was our first attempt to use continuum maximum-entropy maps quantitatively to derive intensities. The explicit background treatment in the present approach represents an advance over the earlier approach. Recent application of an alternative technique is described in Bloemen et al. (1998).

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