

BACKGROUND IN THE MULTIPLE EVENTS (ME) OF SPI/INTEGRAL

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ABSTRACT

Above 100 keV, a significant fraction of the total events in SPI (Vedrenne et al. 2003) is due to the coincident two-detector events ("M"ultiple "E"vents, ME). Including ME in the scientific analysis not only improves the efficiency and sensitivity at high energies (more than 30% above 1MeV, Roques et al. 2003), it also allows polarization measurements which cannot be done with single detector events (see the accompanying proceeding by E. Kalemci on measuring polarization with SPI and its scientific significance). The relative contribution of different background components (localized and non-localized beta decays, prompt emission, etc.) to the ME is different from that to the single-detector events. These differences may produce distributions of line and continuum background rates in pairs of detectors (ME-detectors) that vary from the distribution in individual detectors. Systematic variations in the distribution of background multiple events must be understood in order to perform polarization studies. In this proceeding, we summarize our efforts to understand the nature of the ME variations around the detector plane and their time dependence to enhance the analysis of the ME data for spectral, imaging and polarization studies with SPI.

Key words: INTEGRAL; SPI; Gamma-rays; Background.

1. DATA ANALYSIS METHODS

First, a collection of pointings that do not include strong point sources was selected, and appropriate energy calibration was applied. The data from these pointings: energies, detector pairs, time, dead-time information, as well as Germanium saturation rates, and ACS (anti-coincidence shields) rates (above and below threshold) which could be used as tracers were processed using IDL programs. All the pointings that have problematic data (such as drops in ACS or Germanium saturation rate, or high ACS rates

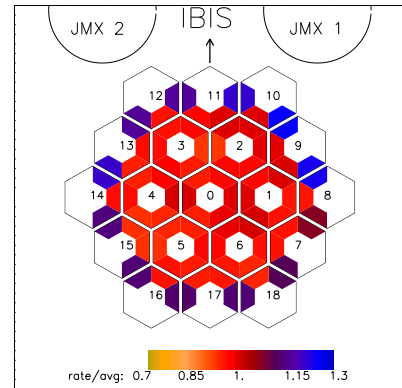


Figure 1. The map of ME continuum count rates with respect to the average count rate in low energy band. The color scale is also shown. The positions of other detectors on the spacecraft are shown for reference (not to scale).

due to GRBs) were eliminated using automatic and visual screening. A dead-time correction that depends on both the ACS rates and individual detector properties has been applied. Since we are more interested in the continuum, all significant lines were filtered out. To investigate the energy dependence, the data were divided into three energy bands of interest, $E < 200$ keV (low energy), $200 \text{ keV} < E < 800$ keV (medium energy), and $E > 800$ keV (high energy).

2. ME CONTINUUM DISTRIBUTION

We have created maps of ME continuum count rates in three energy bands given above using the empty field observations in Revolution 24. First the count rates are normalized with respect to the average count rate, then a color is associated to each rate. The map for the low energy band ($E < 200$ keV) is shown in Fig. 1. This figure clearly shows the large inhomogeneity in the distribution of rates. The outer

detector pairs have higher count rates than that of the inner detector pairs. But the distribution in the outer ring is not homogeneous either. The detector pairs 8-9, 9-10, 10-11 have significantly higher count rates (20-25% higher than the average, see Jean et al. 2003). This region is towards the IBIS and JEM-X1 detectors, which may be responsible for the variations.

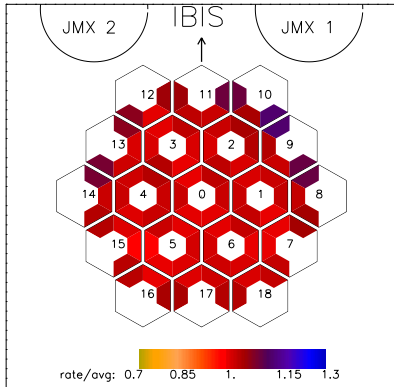


Figure 2. The map of ME continuum count rates with respect to the average count rate in medium energy band.

Fig. 2 shows the map for the medium energy band ($200 \text{ keV} < E < 800 \text{ keV}$). The distribution is still inhomogeneous, but the variation with respect to the average is not as high as the low energy case. Again, the rates toward the other detectors are higher.

At the highest band ($800 \text{ keV} < E < 2 \text{ MeV}$) we investigated, the distribution is more homogeneous (see Fig. 3). There is little excess towards JEM X-1.

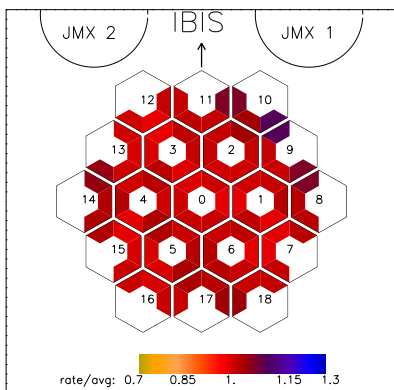


Figure 3. The map of ME continuum count rates with respect to the average count rate in high energy band.

3. ME CONTINUUM, IN DEPTH ANALYSIS

In order to understand the reasons for the background distributions observed, we have conducted more tests. First we investigated whether the continuum background distribution in ME directly reflects the distribution in singles and PSD events. We created a map by merging PSD event rates for each detector in pairs to fake the ME distribution for the highest energy band. This map is shown in Fig. 4. There is an overall resemblance between the fake distribution and the actual ME continuum distribution at high energies shown in Fig. 3.

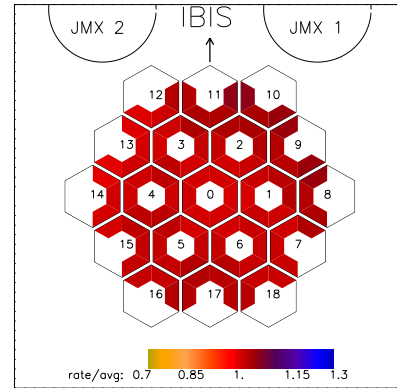


Figure 4. Fake ME distribution at high energy band created by merging PSD background rates.

In the low energy band, the distribution in PSD and single events is not representative of ME events. In the overall spectrum (continuum + lines) the dominant feature in the low energy band is the strong 198 keV line. This line actually consists of a line at 175 keV and a 23 keV internal conversion electron. When we produced coincidence spectra from individual detectors that create the pairs in ME continuum, we realized that the low energy ME are dominated by events which have an internal conversion electron in one detector (23 keV). Fig. 5 shows the strength of this line. In this figure, we also compared the spectrum of a pair with high count rates (8 & 9) to that of a pair with low count rates (0 & 1). It is obvious that the excess for detector pair 8 & 9 is mostly due to this line.

4. TIME VARIATION

An important part of this work is to determine if the background continuum varies with time. A systematic variation depending on known factors can be easily modeled. For this study, data from Revolutions 24, 33 and 70 to 92 are used. We calculated ME count rates with respect to average for each pair (pseudo-detector) for these Revolutions, and plot them in Fig. 6. This figure shows that the distribution does not change significantly with time.

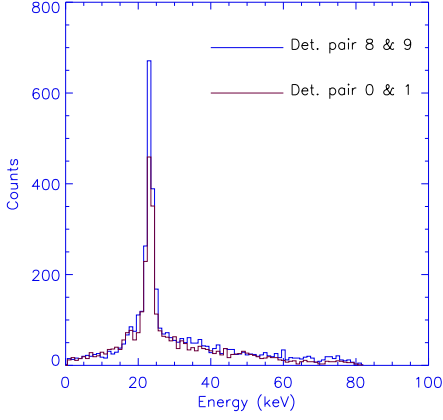


Figure 5. Coincidence spectra from two detector pairs (detectors 8 & 9, with high count rates, and detectors 0 & 1 with low count rates) at low energy. The spectra shown here is from lower energy events in one of the detectors that constitute the pair.

There is no significant evolution at medium and high energy bands either.

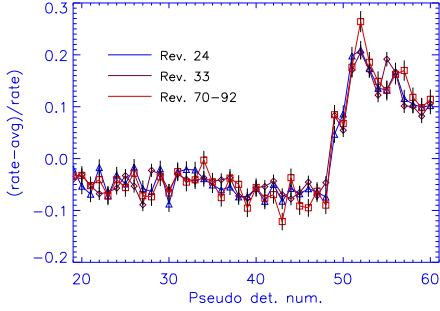


Figure 6. The variation of relative distribution of ME background continuum count rate at low energy. The pseudo-detector representations can be found in SPI User Manual. The pseudo-detectors above 49 represent the outer pairs.

5. TRACERS

Since the time variation of the continuum background in ME is not strong as shown in the previous section, we may be able to roughly estimate this background any time using the earlier observations and tracers. In this work, we tried three cases of comparison between Revolution 27 and Revolution 33: using no tracers, ACS rate as the tracer, and the Germanium saturation rate as the tracer, for the low energy band.

No tracer: In this case, a direct comparison was made without using any tracer:

$$\chi_{ij}^2 = \frac{(r1_{ij} - r2_{ij})^2}{(r1err_{ij}^2 + r2err_{ij}^2)}$$

where i and j are the detector numbers, $r1$ and $r2$

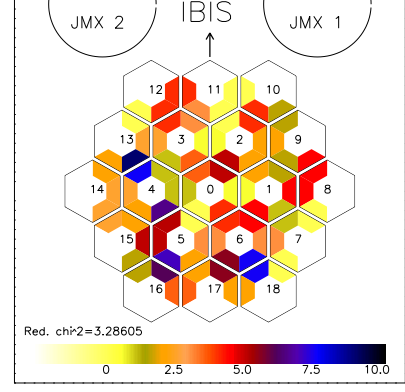


Figure 7. The χ^2 map (see text) of relative count rate distribution in low energy band between Revolutions 27 and 33 for the case of no tracer.

are count rates from two different revolutions, and $r1err$ and $r2err$ are their respective uncertainties. We assigned a color to each χ^2 value, and show the resultant map in Fig. 7. A direct comparison, without using any tracers results in a reduced χ^2 of 3.3. There is no systematic excess of χ^2 in any part of the detector.

ACS above threshold as tracer: In this case the ACS rate above threshold was used as a tracer, the count rates from different revolutions were normalized by dividing the count rates to average ACS above threshold rate for that revolution:

$$r1n_{ij} = r1_{ij}/r1_{acs} \quad r2n_{ij} = r2_{ij}/r2_{acs}$$

$$\chi_{ij}^2 = \frac{(r1n_{ij} - r2n_{ij})^2}{(r1nerr_{ij}^2 + r2nerr_{ij}^2)}$$

where i and j are the detector numbers, $r1_{acs}$ and $r2_{acs}$ are average ACS rates from two different Revolutions, $r1n$ and $r2n$ are normalized count rates from two different revolutions, and $r1nerr$ and $r2nerr$ are their respective uncertainties normalized the same way. The resulting χ^2 map is shown in Fig. 8. There is very significant improvement in the reduced χ^2 value compared to no tracer case as the reduced χ^2 decreased to 1.32 from 3.3

Germanium saturation as tracer: Germanium saturation rates ($gedsat$), unlike the ACS rate, are present for each detector separately. In this case, the total the count rate from each detector pair was divided by the total $gedsat$ from two detectors forming the pair:

$$r1n_{ij} = r1_{ij}/(r1_{gedsati} + r1_{gedsatj})$$

$$r2n_{ij} = r2_{ij}/(r2_{gedsati} + r2_{gedsatj})$$

$$\chi_{ij}^2 = \frac{(r1n_{ij} - r2n_{ij})^2}{(r1nerr_{ij}^2 + r2nerr_{ij}^2)}$$

where i and j are the detector numbers, $r1_{gedsati}$ and $r1_{gedsatj}$ are average $gedsat$ rates from two detectors that form a pair, $r1n$ and $r2n$ are normalized count rates from two different revolutions, and $r1nerr$ and $r2nerr$ are their respective uncertainties normalized the same way. The resulting χ^2 map is shown in Fig. 9. Although there is significant improvement from non-tracer case (reduced χ^2 of 1.68), it is not

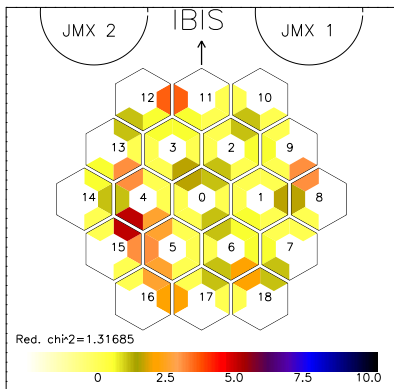


Figure 8. The χ^2 map (see text) of relative count rate distribution in low energy band between Revolutions 27 and 3 using ACS rate as a tracer.

as good as using the ACS as a tracer.

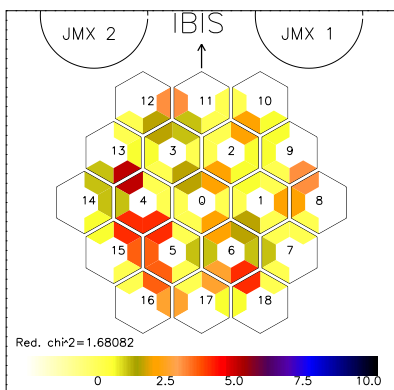


Figure 9. The χ^2 map (see text) of relative count rate distribution in low energy band between Revolutions 27 and 33 using gedsat rate as a tracer.

6. DISCUSSION

The background ME continuum distribution is not homogeneous, at low energies the outer detectors have more count rates than the inner ones. The reason in this case is perhaps the strong 198 keV line. The 23 keV internal conversion electron is likely to be captured in the original site of the line emission but the 175 keV line may escape to the neighbor detector. This 175 keV line, then, could Compton scatter, leaving some portion of its energy in the neighboring detector. If the photon with the remaining energy escapes it contributes to the ME continuum. For the inner detectors, the photon that escaped the neighbor detector would more likely be detected by a third detector, registering the event as a triple rather than multiple, reducing the count rate in the continuum in double events. This background component, in

principle, can be eliminated by checking the 23 keV line feature in one of the detectors. Similar lines exist at higher energies, but they are not as strong as the 198 keV line, which might explain why the higher energy distribution is more homogeneous. Although this explains why outer detector pairs have more count rates than the inner ones, especially for the low energy continuum, additional factors must be contributing to the strong excess towards JEM X-1 and IBIS which is present at all energies. This excess may be due to increased number of secondaries coming from the IBIS and JEM X-1, though variations in the SPI shielding could create similar effects. These two factors are supported by the fact that at high energies, the ME distribution is similar to the distribution of singles.

One important property of the continuum distribution is that it varies little with time. This allows the possibility of estimating the background at different times using earlier empty field observations and tracers. This study shows that using even the simplest ACS rate as a tracer can give reasonably good results. While the Germanium saturation rate was not as good tracer as the ACS rate, perhaps a combination of the ACS rate and Germanium saturation rate would be a better tracer. This possibility is under investigation.

A better tracer with non-evolving background distribution in ME would make polarization studies easier and more reliable. Obviously, the analysis presented here needs to be modified to take into account the loss of Detector 2. This, along with search for better tracers, are subject of future work.

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