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Gamma ray analysis in planetary mapping

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Abstract. In this work, we present ways to improve the analysis procedure for high resolution gamma ray planetary mapping. This study is aimed at providing better analysis procedures for the Gamma Ray Spectrometer (GRS) experiment aboard NASA's Mars Observer Mission. We study how a better estimate of the background from larger regions will improve the study of smaller regions (spectra with low statistics). We also examine how to improve line intensity measurements. Our results show that the major error in line intensity results from the shift in position of the peak with low peak significance. These studies are performed using natural peaks in spectra from controlled laboratory experiment with similar energy resolution.

Key words : gamma ray spectrometer—planetary mapping

1. Introduction

Analysis in gamma ray spectroscopy involves two common steps : (1) the data accumulation and (2) subtracting the background. The uncertainty in the calculated line intensity arises from the Poisson statistics of total data and also from error in derived background (Yadav *et al.* 1989). There are different approaches to determine the background for different experiments. In gamma ray astronomy, where the source rate is usually less than 35% of the background, the background is estimated using off source measurements and further course of analysis depends on if the background varies or not with time and place.

In laboratory counting, one can have very good statistics for background data. In the case of planetary gamma ray mapping, the background continuum is usually derived by subtracting the contributions of different gamma ray lines from total counts (or some other similar approach). From Apollo experiments, we know the continuum emitted from the lunar surface has a substantially larger flux than the sum of all lines in the energy region of interest (Metzger *et al.* 1973). Thus it must be accurately determined in order to derive correct line intensities. This is also true in the case of high resolution gamma ray detectors such as the Mars Observer Gamma Ray Spectrometer (MOGRS) which is launched on the Mars Observer mission. This experiment uses a high resolution HP(Ge) detector. In the case of planetary mapping, one can have a better estimate of the background by using a larger region selected on the basis of some geographical considerations. In this work we study how a better estimate of background will improve the study of local regions.

2. Procedure details

2.1. *Laboratory spectra*

The spectra were accumulated with 140 cc high purity Ge detector in the lab (Yadav & Arnold 1990). The relative efficiency of this crystal is 30.4% compared with that of a 3″ × 3″ NaI(Tl) crystal. The FWHM for ^{60}Co 1.33 MeV line is 1.9 keV and peak to Compton ratio at this energy is 56. Accumulation time varies from 10 hours to 16 days giving a maximum statistical improvement of the order of 40. We use intermediate accumulation time to study peaks of different significance. The spectrum for largest accumulation time 383.2 hours is used to derive the near true position as well as area of the peaks.

2.2. *Computer codes*

In this analysis we have used two different computer programs.

2.2.1. MAINZ CODE

This is an interactive graphics computer program for gamma ray analysis (Kruse 1979). The Mainz code calculates background continuum from the same individual spectrum. It has many options such as peak position free or fixed, FWHM (full width at half maximum) free or fixed, background polynomial degree from one to six, length of the fitted region, etc. In 'free' option, the parameter is determined by program while in 'fixed option' the parameter is present by the user. It analyses for a given option and plots the resulting fit and data points on the screen. One can interact with the program and can alter the options in order to get better estimates. This program uses a cross correlation function for peak search. The fitting function is represented by the sum of a polynomial background and a multi-peak function. The latter is a Gaussian, joined by an exponential on the low energy side. A modified Gauss-Newton algorithm is applied for fitting the data with the function.

2.2.2. GFIT CODE

We developed this program during the course of the present work. Our intention has been to derive the background continuum from a spectrum for large counting time (or from larger regions) as precisely as possible and then use this to study spectra with not so good statistics. To derive the background, we follow the approach of cutting individual peak pasting it by polynomial fit of counts on both shoulders of the peak (if peaks are overlapping or are very close, then we take more than one peak at a time). We use singular value decomposition for polynomial fit (Press *et al.* 1986). The calculated background continuum is smoothed over 5 channels (roughly over the peak width). This approach keeps all large structures in the background continuum. We normalize this background continuum to the spectrum we want to study by comparing total counts in a peak-free region in two different spectra which is consistent with ratio of counting times.

We use zero area convolution with Gaussian transform function for peak search. The fitting function is a Gaussian joined by an exponential tail on low energy side. This program fits individual peak independently. It has options free or fixed for exponential tail parameter, FWHM and position. For nonlinear fitting, we use the Levenberg-Marquardt method which varies smoothly from steepest decent method to inverse Hessian method.

3. Results and discussion

Our analysis shows that peaks with significance less than 9 usually have large errors in the area retrieved. In the case of synthetic peaks, we found this limit at peak significance 4 [synthetic peaks do not subject to the uncertainty of Poisson statistics for real peaks (Yadav *et al.* 1989)]. For the ease of our discussion, we divide peaks into two categories, (1) weak peaks with peak significance < 9 and (2) strong peaks with peak significance ≥ 9. Figure 1 shows the results of position shift (with respect to true value) from the Mainz code as well as the GFIT code respectively. The channel width is 0.5 keV. The strong peaks show zero or small position shift and have small errors in area. The weak peak usually show shift in their peak position and have large errors in area. The range of position shift is smaller for the Mainz code. This may be because the Mainz code fits multi-gaussian peak at a time while GFIT fits one peak at a time. Thus in a situation like overlapping peaks, GFIT may result in a larger shift in peak position which can be avoided by fitting multi-gaussian peaks at a time.

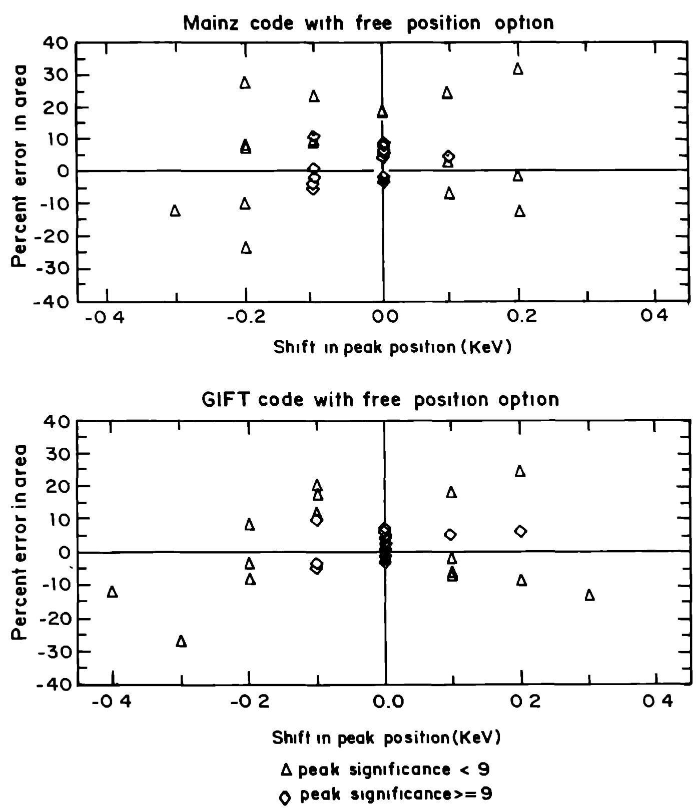

Figure 1. The error in area as a function of shift in the peak position : (a) results from Mainz code and (b) results from GFIT code.

In the above discussion we are talking about shift in peak position which is always less or equal to a channel. It shows that only a few central channels, which have counts well above background, contribute to peak position determination. The statistical fluctuation in the counts of these channels may result shift in the peak position.

The improvement in the background determination (from data with better statistics) does not produce any substantial improvement in the analysis. One of the possible answer is that one is already at statistical limits and an optimized code like Mainz code can provide best results. It is obvious that the statistics of these results are limited due to practical limits in case of natural peaks. However, general trend is clear.

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