THE FINAL COS-B DATABASE: IN-FLIGHT CALIBRATION OF INSTRUMENTAL PARAMETERS

A.W. Strong[4], *J.B.G.M. Bloemen*[1a], *R. Buccheri*[3], *W. Hermsen*[1], *F. Lebrun*[5], *H.A. Mayer – Haßelwander*[4]

The Caravane Collaboration for the COS-B satellite:

1. Laboratory for Space Research, Leiden, The Netherlands
2. Istituto di Fisica Cosmica del CNR, Milano, Italy
3. Istituto di Fisica Cosmica e Informatica del CNR, Palermo, Italy
4. Max-Planck Institut für Physik und Astrophysik, Institute für Extraterrestrische Physik, Garching-bei-München, Germany
5. Service d'Astrophysique, Centre d'Etudes Nucleaires de Saclay, France
6. Space Science Department of the European Space Agency, ESTEC, Noordwijk, The Netherlands

a Sterrewacht Leiden, Huygens Laboratorium, Leiden, The Netherlands

ABSTRACT

A method for the determination of the temporal variation of sensitivity and instrumental background of the COS-B experiment is described, and representative results are presented.

1. INTRODUCTION

The COS-B experiment operated for 6.7 years during which appreciable variations in sensitivity and background occurred. Effective use of these data for scientific analysis requires the determination of the variations and this involves the intercalibration of overlapping observations of the same regions of sky made at different epochs. The final database (described in Mayer-Hasselwander et al. 1985 and this confererence, OG9.3-8) provides ample coverage for such a determination, but owing to the large amount of data involved the problem is not trivial.

Three types of temporal response variation can be distinguished:

(i) long term variations in sensitivity due to degradation in spark- chamber performance

(ii) shorter term period-to-period variations in effective sensitivity due to fluctuations in spark-chamber performance or to the manual editing process

(iii) long-term variations in instrumental background arising from variations in the ambient cosmic-ray intensity.

A method of determination of the variations which uses a non-linear optimisation technique has been successfully applied. The general principle is to use the Galactic diffuse emission as a stable 'calibration source'to compare the response of the instrument at different epochs. The main problem is that observations far apart on the sky are effectively decoupled and this method can give no information on the relative detector response; however the instrument pointing directions were fairly randomly distributed in time so that there should be no correlation between sensitivity and pointing direction, and this can be used as a strong constraint on the solution.

The method is designed to find a set of parameters which lead to maximum consistency between the intensities derived from different observation periods. This will be briefly described and the resulting sensitivity and background variations presented.

2. METHOD

The gamma-ray sky (latitudes $|b| < 30^o$) is divided into ***subcells*** of 1^o square, and the field of view of each observation period (20^o radius) is divided into ***cells*** of 100^o square by raster scans 1^o wide along increasing longitude. For each period i the predicted number of gamma-ray events in subcell j based on the total observations is

$$n_{ij} = f_i e_{ij} \frac{\sum_k (n^o_{kj} - f_k e_{kj} \Delta I_{Bk})}{\sum_k f_k e_{kj}} + f_i e_{ij} \Delta I_{Bi}$$

where the sum is over all periods in which the subcell was observed and

n^o_{kj}= number of events observed in subcell j in period k

f_i= sensitivity relative to the first period ($i = 0$), e_{ij}= nominal exposure (in $cm^2 s$) to subcell j in period i (uncorrected for temporal variations), ΔI_{Bi}= change in background in period i relative to period 0 .

We define

$$\chi^2 = \sum_i \sum_m \frac{r^2_{im}}{N_{im}}$$

where $N_{im} = \sum_{j \subset cell\ m} n_{ij}$, $N^o_{im} = \sum_{j \subset cell\ m} n^o_{ij}$, and $r_{im} = N^o_{im} - N_{im}$.

The background variation was found from independent studies to correlate with the solar-modulated cosmic ray intensity. This confirmed the expectation that the background is due to γ-rays produced by cosmic-ray interactions with the material in front of the telescope. On this basis the ***background variation*** was assumed to have the form $\Delta I_{Bi} = b \Delta S_3$ where ΔS_3 is the change in rate of a scaler sensitive to the total charged particle intensity in the detector. The constant b was determined in the analysis along with the sensitivities.

In order to avoid any correlation of sensitivity with position on the sky (see Sec.1), a ***fluctuation parameter*** S is defined by $S = \sum_i (1 - \frac{f_i}{f^o})^2$, where f^o is chosen to fit the temporal smooth long-term trend. The technique then consists of minimizing χ^2 subject to the constraint of constant S. Suitable values of S were found empirically and adopted in the final determination of the sensitivity and background parameters. Although the method involves about 60 free parameters the number of constraints is much larger than this and the minimization can be performed by suitable conjugate gradient methods (see Strong et al. 1985 for details).

3. RESULTS

Fig 1 shows the variation of sensitivity based on application of the method to data in the range 70 - 5000 MeV. Most evident is the long term variation which causes a 50% reduction over the full time span of the experiment. The method was also applied to the separate energy ranges 70-150, 150-300 and 300-5000 MeV to obtain three independent estimates. The results are consistent with those from the total energy range and show that the period-to-period variations are significant and, further, that the sensitivities are determined with an accuracy which is usually better than 10%. In addition the results in the 3 ranges give an indication of the accuracy of the sensitivity determination in individual periods.

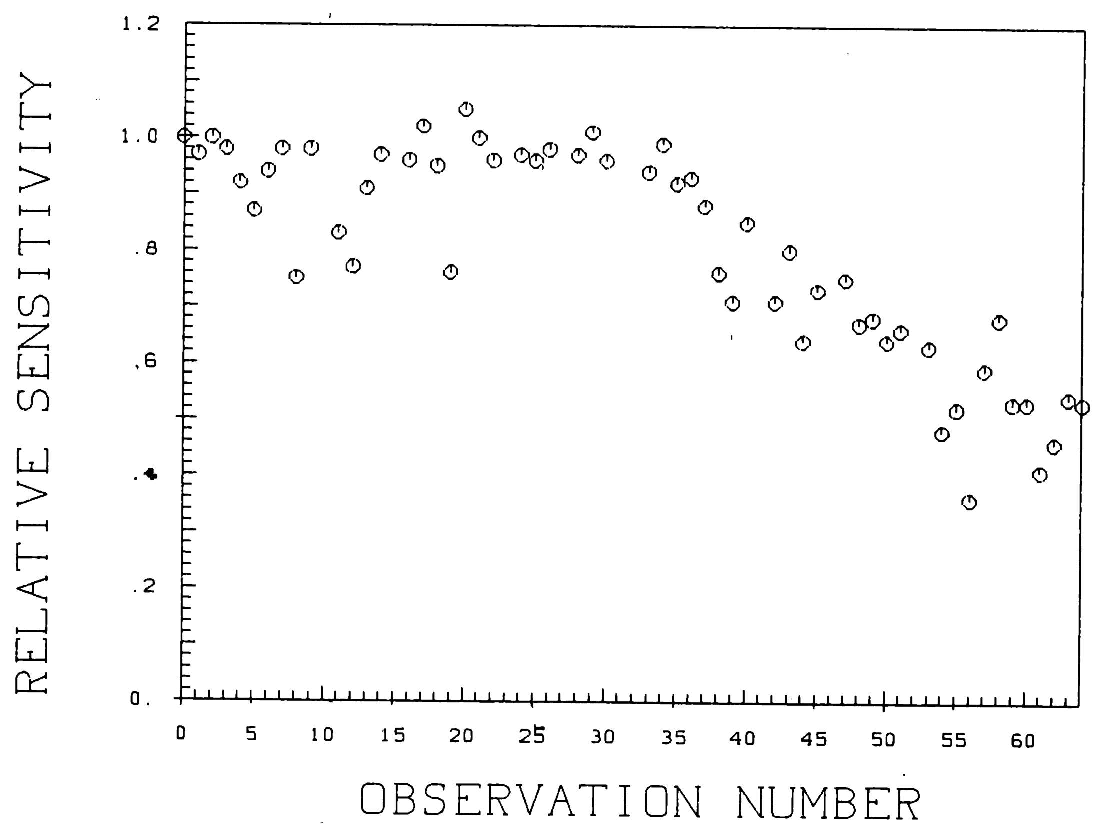

FIG 1. *Relative sensitivity as function of observation period determined for the 70-5000 MeV energy range using the method described in the text. The sensitivity of the first period (Period 0) is taken as 1.0. Periods pointed at high latitudes with insufficient overlap are not displayed.*

There is no trend visible when the sensitivities are plotted as a function of Galactic longitude, demonstrating the success of the technique described above. The larger fluctuations in sensitivity can be identified as originating in known effects such as instrumental malfunctions, and where an independent estimate of the size of the effect can be made the agreement is satisfactory.

Fig 2 shows as an example the background variation in the energy range 300-5000 MeV. The total variation amounts to about 30% of the average absolute background level.

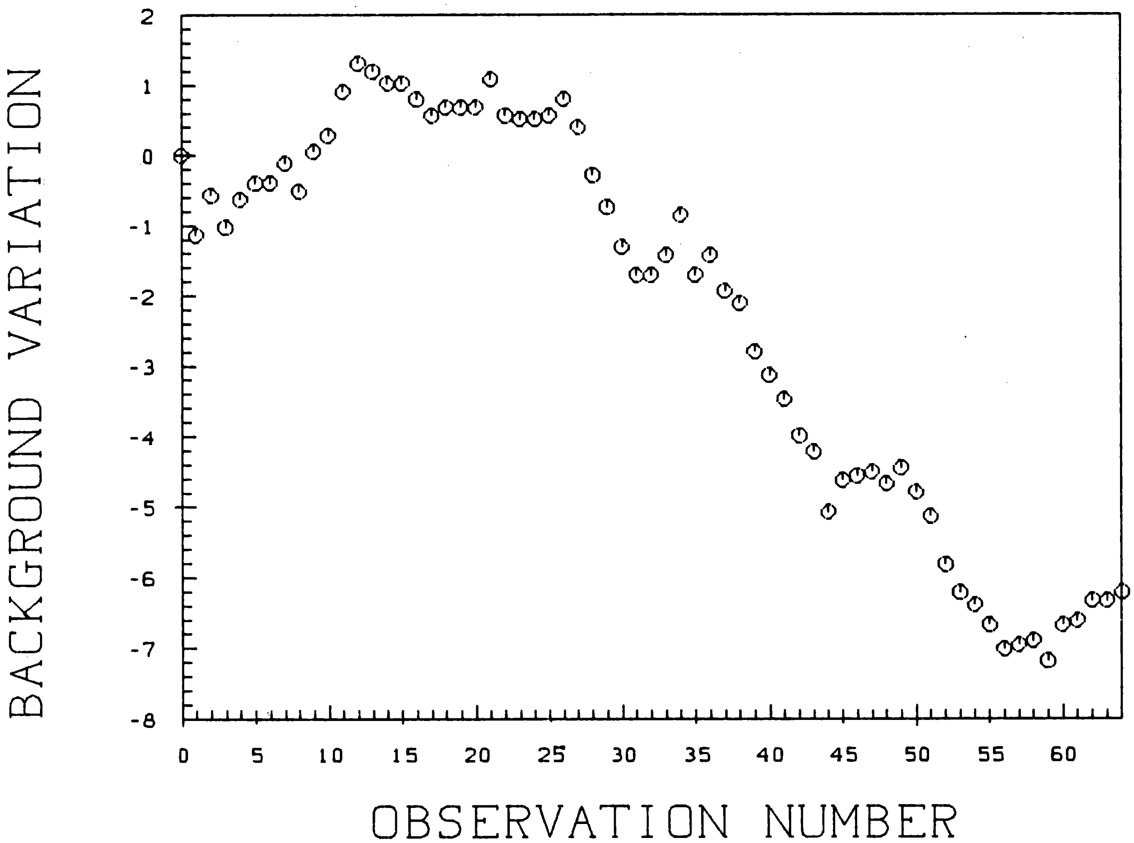

FIG 2. *Variation of background level relative to first period for the 300-5000 MeV energy range. Units:* 10^{-6} *ph* $cm^{-2}sr^{-1}s^{-1}$. *The variation is assumed proportional to the rate in a charged particle scaler, with a constant of proportionality determined from the overlap analysis.*

A complete description of the method and results will be given in Strong et al. (1985).

REFERENCES

Mayer-Hasselwander H A et al. (1985) *in preparation*

Strong A W et al. (1985) *in preparation*