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MULTICOMPONENT ANALYSIS OF TOTAL COS-B GAMMA-RAY DATA AT INTERMEDIATE LATITUDES

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ABSTRACT

The final COS-B database has been used to study the gamma-ray emission in the latitude range $10^o < |b| < 20^o$ in terms of a four component model. The emissivity spectrum of the local interstellar medium is derived and compared with that found in previous studies. The intensity of the inverse-Compton component is determined from the fitting procedure and is in good agreement with theoretical values.

1. INTRODUCTION The gamma-ray emission from the galaxy in the intermediate latitude range $10^o < |b| < 20^o$ has been the subject of several studies (Lebrun et al. 1982, Strong et al. 1982, Strong 1985a). This region is important in understanding the nature of the local emission and as a guide to the interpretation of the larger scale emission. We present here results using the final COS-B database (Mayer-Hasselwander et al. this conf. OG9.3-8) combined into skymaps using the parameters derived by Strong et al. (this conf. OG9.3-9). The final database includes a significant amount of additional information from the last 10 observation periods, not previously used. The data are analysed using the 4-component model described by Strong (1985a) and the information matrix technique of Strong (1985b); the reader is referred to these papers for more details.

2. MODEL AND RESULTS The model includes emission from atomic and molecular hydrogen, inverse Compton emission and an isotropic background (instrumental and celestial). The atomic hydrogen column density is derived from 21-cm surveys, and the molecular hydrogen column density is estimated using both galaxy counts and 21-cm data. The surveys and their use are described in Strong (1985a). The four parameters of the model are: q_1 (emissivity of atomic hydrogen), q_2 (emissivity of molecular hydrogen), f_{ICS} (a dimensionless scaling factor for the inverse Compton component) and I_B^o (the 'on-axis' background level). The result of a likelihood analysis of a multivariate problem of this kind can be concisely summarized in the form of the diagonalized 'information matrix' Q. In this formulation

the log likelihood function L is given by

$$L = L_o + \sum \lambda_i x_i^2$$

with

$$x_i = \sum Q_{ji} \vartheta_j$$

Here L_o is the maximum of L , λ_i are the eigenvalues of the information matrix and ϑ_i are the deviations of the parameters from their maximum- likelihood values. The n-dimensional confidence region for the parameters is thereby completely specified, and confidence regions for subsets of parameters can be computed using Q as described in Strong (1985b). Table 1 gives the maximum-likelihood values of the parameters, Q and λ_i for the three energy ranges considered (70-150, 150-300 and 300-5000 MeV). The 1-parameter errors (1σ, $\Delta L = 0.5$) derived from Q are given. The model fit to the total energy range 70-5000 MeV is shown in Fig 1.

(a) MAXIMUM LIKELIHOOD PARAMETERS OF THE MODEL

ENERGY RANGE	q1/4π	q2/4π	I$_B$	f$_{ICS}$
	10^{-26} sr^{-1} s^{-1}		10^{-5} cm^{-2} sr^{-1} s^{-1}	
70- 150 MeV	1.10 ±.14	0.96 ±.22	7.16 ±.27	1.32 ±.39
150- 300	0.76 .09	0.49 .12	2.51 .17	1.31 .57
300-5000	0.68 .09	0.405 .10	2.19 .15	0.60 .52

(b) INFORMATION MATRICES: Eigenvectors (* 100)

70-150 MeV	:	150-300 MeV	:	300-5000 MeV
-01 45 29 -84	:	-01 46 24 -85	:	00 49 27 -83
-39 23 -87 -18	:	-15 14 -96 -20	:	-14 11 -95 -25
-22 -86 -02 -46	:	-09 -87 -01 -48	:	-10 -86 04 -49
89 -11 -38 -20	:	98 -05 -14 -09	:	99 -07 -13 -09

Eigenvalues (units as in (a))   :

2.69 5.93 27.90 245.3 :1.53 15.48 69.44 613.9: 1.84 18.43 90.74 710

TABLE 1. Results of likelihood analysis for the 4-component model

3. DISCUSSION The results of the fitting are quite consistent with those given in Strong (1985a), and with the improved statistics the resulting errors are smaller. Note that the uncertainty in f_{ICS} is now included in the error estimates of all the parameters. The value for f_{ICS} found here is consistent with that expected (1.0) for the model described in Strong (1985a), and in fact it is remarkable that the ICS component can now be determined with reasonable accuracy by this method. The overall fits are a noticeable improvement over Strong et al. (1982), and give confidence in the reliability of the fitted parameters.

The *main result* of this analysis is the determination of the emissivity spectrum associated with atomic hydrogen (q_1); since the 21-cm HI column densities are

reliable and since q_1 is not strongly coupled to other parameters of the model, this emissivity spectrum can be used with confidence. Comparing with an analysis of the large- scale emission using HI and CO data (Bloemen et al., this conference,) we find excellent agreement between q_1 and the average emissivity between 8 and 15 kpc galactocentric distance. Since the two methods are quite independent, this adds further to our confidence in the reliabilty of this emissivity spectrum, of particular importance to analyses which attempt to interpret this spectrum in terms of a sum of π^o-decay and bremsstrahlung emission (see eg. Gualandris and Strong 1984, and Strong, this conference, OG3.1-7)

As noted in the previous studies, the gamma-ray data show an excess over the predicted intensity in the region $10^o < b < 20^o$, $20^o < l < 40^o$; more important, the North-South asymmetry seen in the gamma rays is not predicted by the gas or the inverse-Compton components. This excess is in spatial coincidence with the North Polar Spur, and it is plausible to attribute it to increased cosmic ray intensity there, since there is independent evidence from purely radio data for an enhancement of cosmic ray electrons (Heiles et al. 1980 derived a factor of 20 ,which would be sufficient to give the observed effect).

Apart from this region, the agreement of the observations with the model is about as good as could be expected, except in the region centred on $l = 120^o$ South of the plane, for which the observed intensities appear systematically low. In order to assess the origin of this effect, we checked on which COS-B observation periods contribute to this region; it is dominated by only one period, which has relatively small overlap for the determination of relative sensitivity (see Strong et al. this conference, OG9.3-9). The uncertainty in sensitivity would be sufficient to explain the effect and therefore the disagreement in this region is not a serious problem for the interpretation.

In the region $l > 240^o$, for which galaxy counts are not available, the emission from HI and ICS alone is sufficient to give the observed intensities South of the plane, but rather low North of the plane. We note that Feitzinger and Stüwe (1984) have provided maps of the absorption in this longitude range based on star counts, and these indicate excess absorption North of the plane, consistent with the present results.

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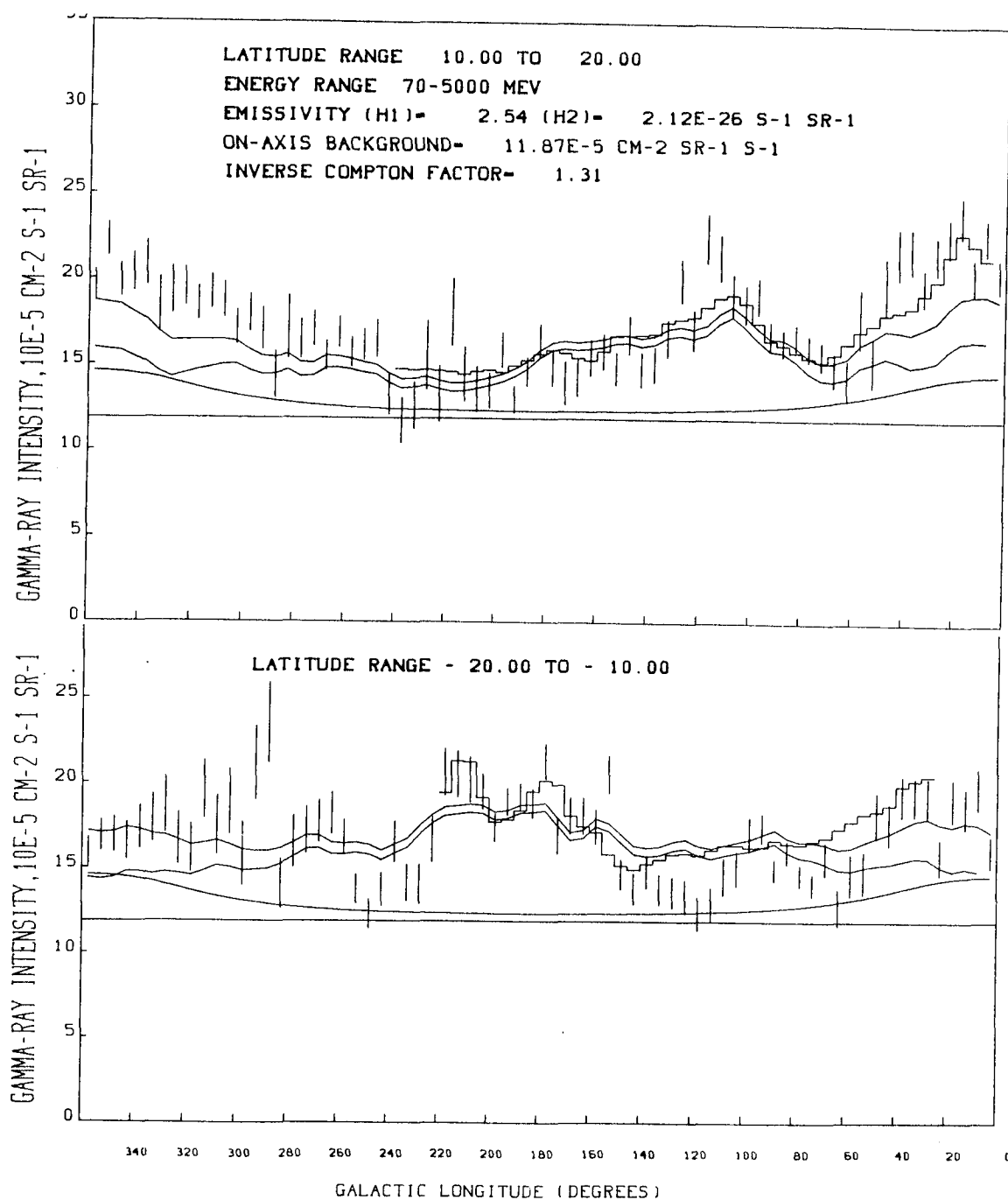**Strong A W** (1985b) *Astron.Astrophys. in press*

FIG 1 *Longitude distribution of COS-B gamma-ray intensity for $10^o < b < 20^o$ and $-20^o < b < -10^o$ compared to the predictions of the model described in the text.* **VERTICAL BARS:** 1σ statistical limits on COS-B intensity, **HORIZONTAL LINE:** fitted on-axis background level, **LOWER CONTINUOUS LINE:** inverse Compton emission plus background, **MIDDLE CONTINUOUS LINE:** emission from atomic hydrogen plus background, **TOP CONTINUOUS LINE :** sum of atomic hydrogen, inverse Compton and background, **HISTOGRAM :** sum of all 4 components