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COS-B GAMMA-RAY SOURCES BEYOND THE PREDICTED DIFFUSE EMISSION

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ABSTRACT

COS-B data have been reanalysed using for background subtraction the modelled galactic diffuse gamma-ray emission based on HI- and CO-line surveys and the gamma-ray data itself. A methodology has been developed for this purpose with the following three features: automatic generation of source catalogs using correlation analysis, simulation of trials to derive significance thresholds for source detection, and bootstrap sampling to derive error boxes and confidence intervals for source parameters. The analysis shows that about half of the 2CG sources are explained by concentrations in the distribution of molecular hydrogen. Indication for a few weak new sources is also obtained.

I. INTRODUCTION

The question of the nature of those galactic gamma-ray "point-sources" (Swanenburg et al. 1981) which are not identified with objects visible in other wavelength regimes has been outstanding for some years. While two well-known sources, the Crab- and Vela-pulsars, demonstrate the existence of compact objects emitting gamma rays in the > 70 MeV regime, the emission of gamma rays by interaction of galactic cosmic rays with the interstellar gas and with galactic photon fields also is a well-known fact. Concentrations in the galactic molecular-hydrogen distribution are seen in CO-emission-line surveys (e.g. Dame and Thaddeus 1985). Such concentrations in the gas distribution, irradiated by the ambient galactic cosmic-ray flux, are good candidates for some of the 2CG sources. The search for point sources, which cannot be explained by emission from gas, is motivated by the interest in narrowing down as far as possible this class to galactic objects which are really compact. The better the diffuse background emission is known, the better the population of really compact gamma-ray objects can be defined.

II. METHOD

The inputs are the distribution of diffuse gamma-ray emission predicted using tracers of HI and H2 (Bloemen et al. 1986, Strong et al. 1989), a model of the inverse Compton emission, and the COS-B gamma-ray data. Within a few degrees of longitude from the galactic center the model breaks down, there the data are interpolated from the values in neighbouring longitude bins. The gamma-ray data used is the final COS-B database (Mayer-Hasselwander et al. 1985, Mayer-Hasselwander 1985). The data are analyzed in three energy ranges: 70-150, 150-300, and > 300 MeV. The analysis consists of three phases: 1) accidentals rate definition, 2) catalog generation, 3) and source parameter study. For a description of the method see Mayer-Hasselwander and Simpson (1988). In addition to the crosscorrelation estimator, also the likelihood estimator used by Pollock et al. (1985) has been applied leading to very similar results. Results for 1) and examples for 3) have been published by Simpson and Mayer-Hasselwander (1986) and Simpson and Mayer-Hasselwander (1987). The significance thresholds were chosen such, that 0.33 accidental sources can be expected in each of the three energy ranges, or 1 source in all three. This criterion gave the following threshold values (sigma): 70-150 MeV: 4.1, 150-300 MeV: 3.9 and > 300 MeV: 3.7.

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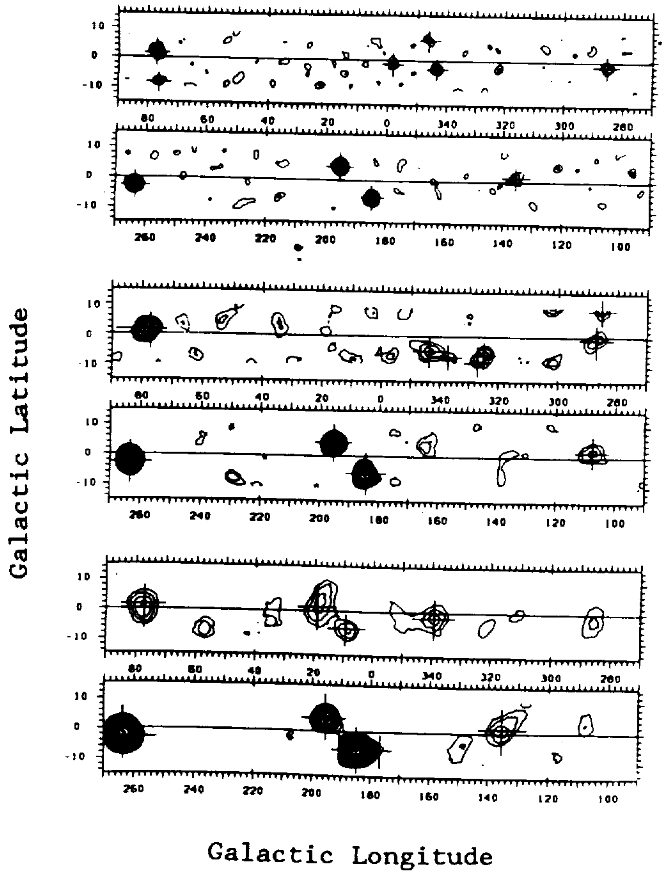
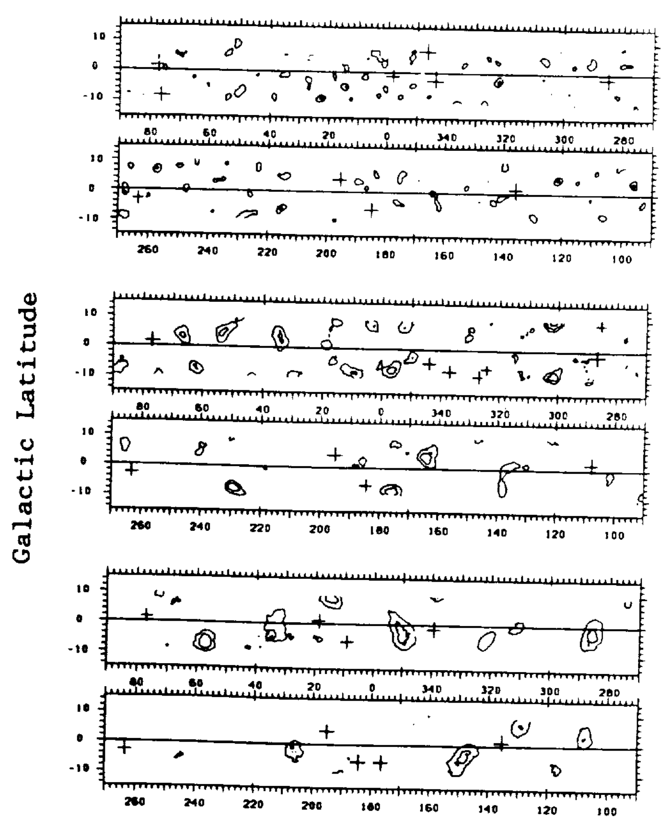


> 300 MeV

150 - 300 MeV

70 - 150 MeV

Fig. 1a.--Significance maps of crosscorrelated signal. Lowest contour is at 2 sigma, contour intervals are 1 sigma. Crosses indicate source locations.



> 300 MeV

150 - 300 MeV

70 - 150 MeV

Fig. 1b.--Significance maps after removal of all signals detected above threshold. Contour lines as in figure 1a.

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III. RESULTS

The revised catalog is presented. The original significance maps are shown in Figure 1a and the residual significance maps after subtraction of all sources above threshold are given in Figure 1b. The results refer to the latitude range b < 10° and in the tables are grouped in three classes: confirmed 2CG-sources, 2CG-sources explained by gas concentrations, and new sources.

Confirmed 2CG-sources:
From the 22 2CG-sources within the field analyzed here, only 8 are detected above the significance threshold after subtraction of the predicted diffuse emission. Slightly different parameters are found for these sources as listed in Table 1. Differences are to be expected, since the subtraction of the structured diffuse-emission background may cause the source peaks to shift and to alter in amplitude. The source locations refer to the highest energy range within which the source is detected.

TABLE 1

CONFIRMED "2CG" SOURCES

2CG name	position+		> 300 MeV		150-300 MeV		70-150 MeV	
	L	B	flux $cm^{-2}s^{-1}$ $*10^7$	sigma	flux $cm^{-2}s^{-1}$ $*10^7$	sigma	flux $cm^{-2}s^{-1}$ $*10^7$	sigma
2CG078+01	77.2	+1.8	4.6	6.5	7.9	7.4	11.3	5.3
2CG135+01	135.8	+1.0	2.8	4.5	10.0	2.2	10.2	5.0
2CG184-05	184.5	-5.9	7.0	8.9	10.8	10.3	34.5	13.7
2CG195+04	195.2	+4.2	13.3	12.4	12.8	11.8	21.8	10.2
2CG263-02	263.6	-2.6	37.6	19.1	35.6	17.8	59.5	17.2
2CG284-00	285.2	-1.8	5.8	4.2	6.6	3.9	12.3	3.5
2CG342-02	343.5	-2.9	4.7	4.6	6.5	4.6	16.3	4.7
2CG359-00	358.0	-1.4	3.5	3.7	-	-	-	-

+ position as derived in > 300 MeV energy range

2CG sources explained by gas concentrations:
Within the area analyzed, 14 of 22 2CG-sources are not detected above the statistical significance threshold. In the majority of the cases actually no positive signal is detected, indicating that the excesses are fully attributable to gas enhancements. In the case of 2CG036+01, 2 and 3 sigma excesses still are seen in two neighbouring energy ranges giving some support for the existence of this source. These 2CG-entries are listed in Table 2 for completeness.

New sources:
It is clear that all the stronger sources must have been found in earlier analyses. So all the 9 new sources listed in Table 3 are rather weak and are detected above threshold in one energy range only. In some cases excesses are seen in more than one energy-range; this makes the source at 176.4-5.6 especially interesting. It is difficult to assess the "point-source" quality for these sources: most are seen in the lower energy ranges where the point-spread-distribution is wide. If they are not point-like, the excesses would indicate local inadequacies of the background model. It is noteworthy that in directions to the inner Galaxy the latitude distribution of the new sources is wider than the latitude distribution of the diffuse emission. This can be understood as a twofold selection effect: only nearby sources are intense enough to be detectable individually and, in

TABLE 2

"2CG" SOURCES EXPLAINED BY GAS CONCENTRATIONS OR WITH SIGNIFICANCE BELOW THRESHOLD

2CG name	Remarks
2CG006-00	no excess
2CG013+00	no excess
2CG036+01	2 and 3 sigma excesses in low and medium range
2CG054+01	no excess
2CG065+00	no excess
2CG075+00	2 sigma excess in high range only; confusion by source at l = 77.2 not excluded
2CG095+04	3 sigma excess in high range only
2CG121+04	3 sigma excess in high range only
2CG218-00	2 sigma excess in medium range only
2CG235-01	no excess
2CG288-00	no excess
2CG311-01	2 sigma excess in low range only
2CG333+01	no excess
2CG356+00	no excess

TABLE 3

NEW SOURCES INDICATED BY THIS ANALYSIS

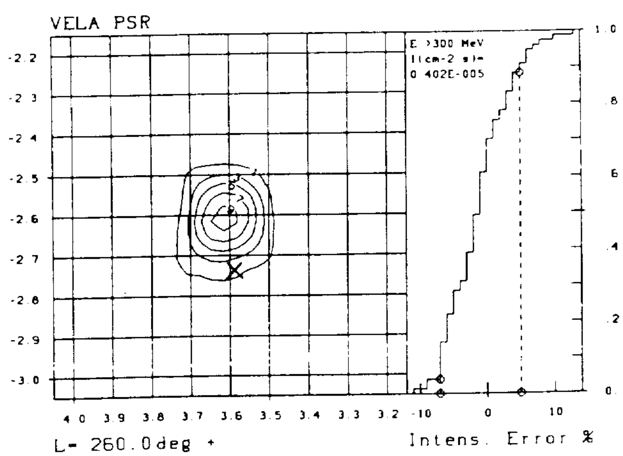
Position* L deg	B	> 300 MeV flux $cm^{-2}s^{-1}$	sigma	150-300 MeV flux $cm^{-2}s^{-1}$	sigma	70-150 MeV flux $cm^{-2}s^{-1}$	sigma	Remarks
9.6	-5.7	-	-	-	-	12.0	4.7	
18.6	+1.4	-	-	4.1	2.2	17.5	4.7	extended?
76.4	-8.1	1.4	4.1	-	-	-	-	
107.4	+1.9	-	-	5.9	4.3	7.0	3.2	
176.4	-5.6	1.0	2.0	1.5	3.2	5.7	4.2	extended?
285.1	+8.7	-	-	5.2	4.2	-	-	
324.7	-6.1	-	-	5.3	4.5	-	-	
327.2	-8.7	-	-	1.7	5.0	-	-	
336.8	-6.9	-	-	4.2	4.0	-	-	

addition, even nearby sources, if at low latitudes in the 1st or 4th quadrant, are buried in the high statistical fluctuations caused by the intense diffuse emission seen towards the inner Galaxy.

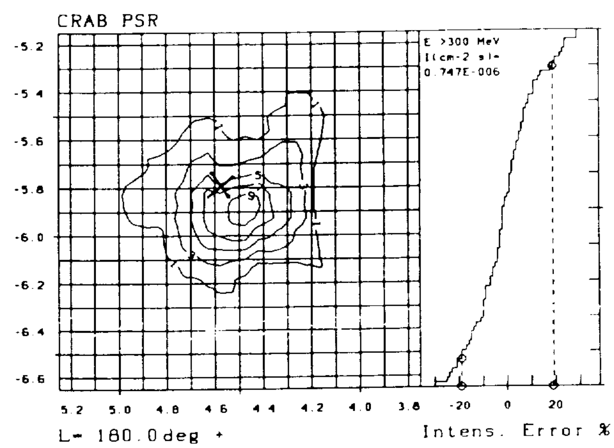
Of specific interest is the source seen in the low and medium energy range with a maximum at l = 18.6, l = + 1.4, which well may correspond to possible pulsed gamma-ray emission from the new binary PSR 1820-11, for which Li and Wu (report December 1988) claim to have found evidence in the COS-B data.

Confidence Intervals:
Using the Bootstrap method, error boxes and the intensity uncertainty is derived directly from the data. These results are presented for the sources seen in the energy range >300 MeV in the figures 2 a to 2i. The uncertainty of the source location is given by the probability density distribution which is indicated by contour levels. The maximum value is normalized to equal 10. The crosses indicated for the Vela- and Crab- PSRs are well within the derived error boxes and give confidence that the systematic attitude measurement error of the COS-B satellite is not significantly deterioriating the instruments source-locating capabilities. For the source 2CG195+04 the identification with the source E 0630+178, respectively the optical source G", as suggested by Bignami et al. (1983, 1988) has gained likelihood through the reduced errorbox derived in this analysis.

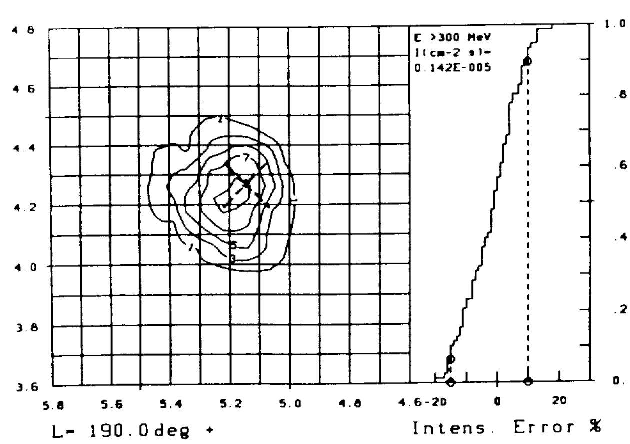
Fig. 2.--Errorboxes and intensity distributions for sources observed in the energy range >300 MeV. The crosses in figures a) and b) indicate the actual pulsar positions. The cross in figure c) indicates the position of the tentative counterpart E 0630+178. The contour levels indicate relative probabilties to find the source at a given postion, if the experiment is repeated. The integral intensity distribution indicates the error of the intensity determination; the dashed lines indicate the 80% confidence interval.



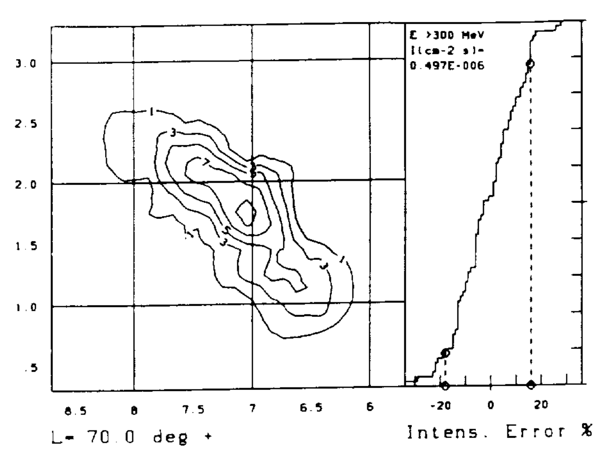
a)



b)



c)



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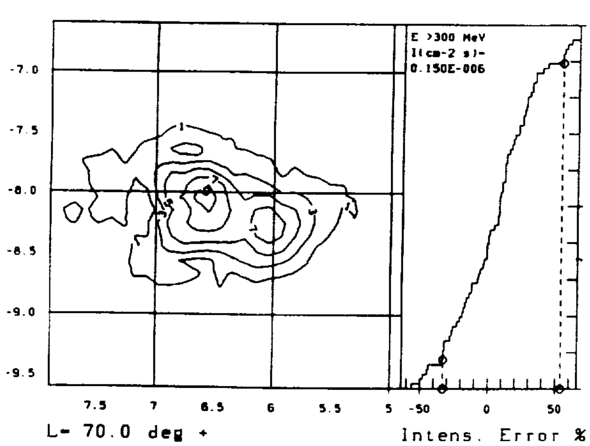

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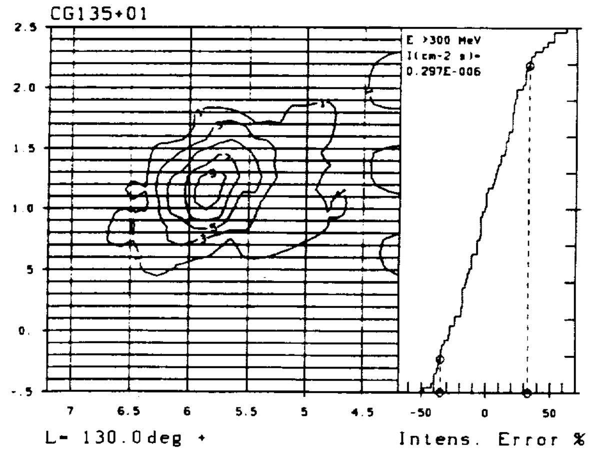

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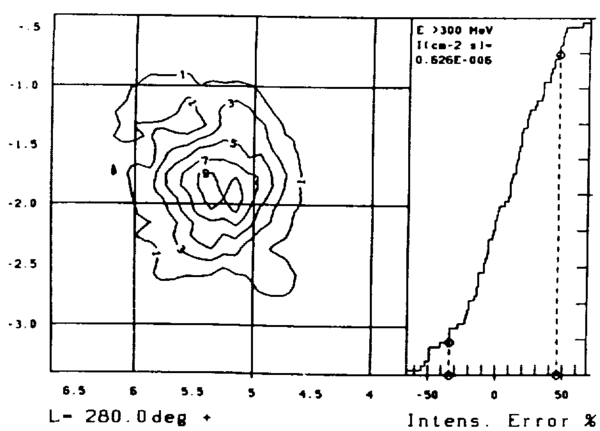

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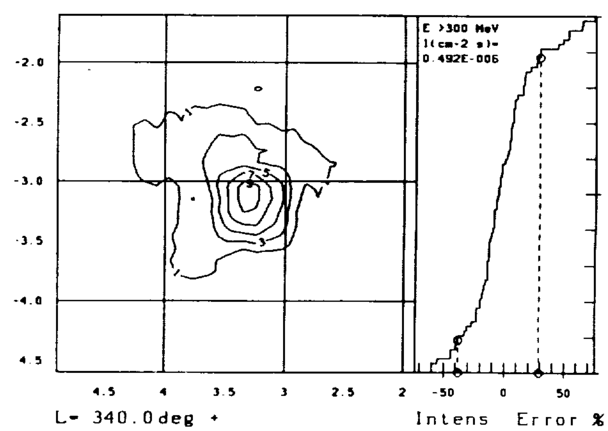

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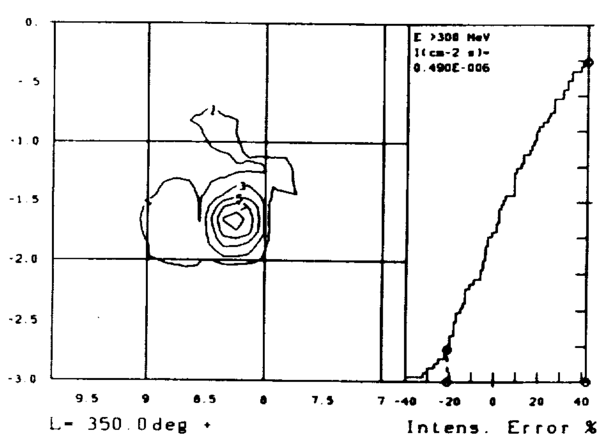

i)

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IV. CONCLUSION

The analysis shows that the "diffuse" gamma emission from gas - cosmic-ray interaction is the likely explanation for about half of the 2CG sources. Several sources remain as interesting counterparts for compact objects or active regions. A number of new source candidates were detected. As most are seen in the lower energy ranges, where the angular resolution is rather limited and systematic uncertainties in the analysis are larger, and as their intensity is relatively low, these enhancements should be taken as indications only. They clearly need confirmation by the new gamma-ray telescopes soon to be launched.

ACKNOWLEDGEMENTS

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DISCUSSION

Floyd Stecker:

After subtracting out a diffuse background based on gas density, can you say if the remaining source in Cygnus must be point-like, or could it still be diffuse?

Hans Mayer-Hasselwonder:

The remaining excess appears to be elongated over about 1.5 degrees. This can be taken as an indication for having two neighboring sources. These sources as well could be really compact objects or unresolved hot spots in the cosmic-ray distribution or gas concentrations not seen in CO-line observations.