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COS-B γ-RAY SOURCES AND INTERSTELLAR GAS

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1 Introduction The detection of localised sources of high-energy γ-radiation, first by SAS-2 and later more comprehensively by COS-B, has lead to much discussion regarding the physical nature of the objects that number 25 in the 2CG catalogue (1). Only the Crab and Vela pulsars have been unambiguously identified; the ρ Oph cloud has subsequently been resolved ; and 3C273 (2) and the X-ray source 1E0630+178 (3) have also been proposed as counterparts. The status of the remaining sources is much less clear. Of the γ-radiation observed above 100 MeV only a few percent is due to the catalogued sources which are viewed against intense background emission from the galactic plane. There has been considerable recent success in modelling the galactic plane emission as the interactions of cosmic rays with atomic and molecular interstellar gas; elsewhere at this conference Bloemen et al (4) demonstrate that the large angular scale features of the observations are well reproduced in this way. By extending the analysis to small angular scales we aim to show which of the 2CG sources might be due to conventional levels of cosmic rays within clumps of gas and which cannot be so explained. With the use of a more sophisticated model the results presented here improve and extend those of an earlier report (5). So far we have only used the data above 300 MeV where the instrument's angular resolution is at its best. Work at lower energies is also underway.

2 Analysis A combination of HI measurements and the recent Columbia/GISS large scale CO survey allows a detailed and independent point-by-point estimate of the diffuse emission above which any sources appear. Using Bloemen et al's (4) model as a starting point we have used a likelihood method (5) to test for the presence of point sources in addition to

the gas. The area surveyed covers $12° \leq l \leq 179°$ in the first and second quadrants of the galaxy and $271° \leq l \leq 299°$ in Carina. The extent of the latitude coverage varies slightly with longitude although for $-5° \leq b \leq +5°$ it is complete. For each of the 17 relevant COS-B observations one seeks a probability model of the form

$$p(l,b)d\Omega \propto (r_s p_s(l_s,b_s)+p_g)d\Omega$$

to describe the photons detected over the entire field of view within the CO survey boundaries. r_s is the strength of a source at (l_s,b_s), p_s has the form of the COS-B point-spread function and p_g comes from Bloemen et al's model of the diffuse emission. The choice of the appropriate parameters is made through values of the log likelihood

$$\ln L = \sum_i \ln(p_i)$$

for the set of detected photons. lnL is a maximum for some value $r_s=r_{max}$ and the statistic

$$\lambda(l_s,b_s) = \ln L(r_{max},l_s,b_s) - \ln L(0,l_s,b_s)$$

gives the weight of evidence for a point source. λ^* is λ maximised with respect to position. A value of 6, which we adopt below as a threshold, corresponds to a random probability of a few percent.

3 Results and Discussion The λ^* statistic shows that some point-like sources must be added to the diffuse emission to reproduce the data above 300 MeV. Table 1 is a summary of the results giving positions, fluxes and λ^* values. The list has entries for new sources with $\lambda^* > 6$ and, with the exceptions of 2CG284-00 and 2CG288-00 which coincide largely with two new entries, for each of the 2CG sources in the area surveyed whether detected here or not. The inclusion of the background model has caused some changes in flux and position from 2CG catalogue values. We have also found that the improved model used here has caused flux changes of up to 20% with corresponding changes in λ^* compared with the earlier work of Pollock et al (5).

By far the most significant feature is the excess in Cygnus which is resolved into two point sources corresponding to 2CG078+01 and 2CG075+00. These lie 2.7° apart near the edge of the large complex of atomic and molecular gas in the Cygnus X region. Although it is possible that we are dealing with an extended feature, two independent sources seem the more likely explanation: the intensities along the line joining the two sources show two reasonably well resolved bright spots that do not have counterparts in the gas data. 2CG078+01 is closely coincident with SNR G78.2+2.1, one of the brightest radio

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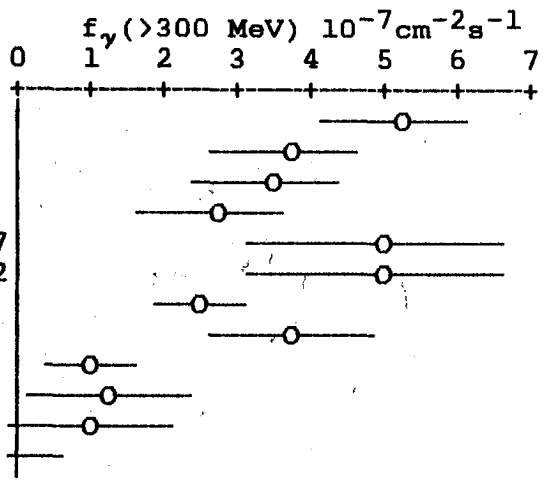
TABLE 1

object	l°	b°	λ*	m
2CG078+01	78.1	2.3	60.9	7
2CG075+00	76.1	0.5		7
284-01	284.7	-1.8	12.0	2
286+00	286.8	0.6		2
083+03	83.0	3.1	8.4	1/7
2CG054+01	55.0	2.2	8.3	1/2
2CG135+01	135.1	1.0	7.7	2
2CG013+00	14.0	0.3	5.9	4
2CG095+04[c]	95.5	4.2	2.5	4
2CG036+01[c]	36.5	1.5	1.6	5
2CG121+04[c]	121.4	4.0	0.9	2
2CG065+00[c]	65.7	0.0	0.0	4



Summary of the search for point-source emission above the gas in the COS-B data above 300 MeV. l and b are galactic coordinates which for those objects marked [c] are taken from the 2CG catalogue. The positions are uncertain to between 0.5° and 1.5°. λ^* is the likelihood statistic described in the text. m is the number of observations made : 2CG054+01 was only detected in 1 out of 2 observations and 083+03 in 1 out of 7. f_γ is the flux above 300 MeV with approximate $\mp 1\sigma$ errors.

remnants. Pollock (6) argues for identification with the synchrotron-emitting region behind the shock front.

The second of the seven observations of Cygnus showed a source at 083+03 which did not appear at other times. It is therefore a variable or transient source. Similarly 2CG054+01 appeared in one of two observations. These are the first clear examples at these energies of such phenomena whose existence was suggested by Bloemen et al's (7) early analysis of COS-B data. Given the implied variability time scale of roughly a year it is probable that these are compact objects.

There is an extended excess in Carina that suggests two adjacent point sources and evidence of emission from 2CG135+01 and 2CG013+00. As for the other 2CG sources, the evidence for excess emission is weak and it is likely that they find an explanation in terms of clumps of gas irradiated by a normal flux of cosmic rays. General proposals along these lines have been made by several authors, notably Li and Wolfendale (8).

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