THE LOCAL INTERSTELLAR MEDIUM AND GAMMA-RAY ASTRONOMY

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ABSTRACT

The recent improvement of the calibration of the galaxy counts used as an interstellar-absorption tracer modifies significantly the picture of the local interstellar medium (ISM). Consequently, previous analyses of the γ-ray emission from the local ISM involving galaxy counts have to be revised. In this paper, we consider the implications regarding the cosmic-ray (CR) density in the local ISM, and in particular within Loop I, a nearby supernova remnant (SNR).

<u>1. Introduction</u> Since the initial proposal of Puget *et al.* (1) to use interstellar absorption as a total-gas tracer, galaxy counts have been widely adopted to predict the interstellar γ-ray emission (2,3,4,5). However, all these analyses rely on the uniformity of the gas to dust ratio, which has been often questionned (6,7,8), casting some doubt on the validity of galaxy counts used as gas tracer, principally in the Oph-Sag region of the sky, where extremely large gas column-densities are suggested by galaxy counts. The γ-ray fluxes observed in that region would indicate even larger column densities; however, it has been argued that these high γ-ray fluxes are due to an enhancement of the CR intensity within the Loop I (North Polar Spur) SNR (9,10). Moreover, Lebrun (11) shown that the gas density in Oph-Sag cannot be as high as indicated by both galaxy counts and γ-ray data. He suggested that the low galaxy counts in Oph-Sag results from a degradation of the detectability of faint galaxies, due to a high field-star density rather than overabundant dust, and he proposed to attribute the γ-ray excess to Loop I. Recently, Lebrun (12) demonstrated that indeed, the detectability of galaxies depends strongly on the star density and that such an effect is strongest in Oph-Sag. In the following, we aim to investigate the implications of this finding on the interpretation of the locally produced diffuse γ-ray emission.

<u>2. The data</u> Our analysis uses the celestial γ-ray intensity I_γ, and the total gas column-density N_H, derived from galaxy counts. We basically follow the method described in our previous paper (13), with the two exceptions that the galaxy counts are now corrected for the effect of field stars (12), and that the angular resolution of the γ-ray telescope is taken into account.

The γ-ray intensity in two energy ranges ($35<E_\gamma<100$ MeV and $E_\gamma>100$ MeV), was derived from the *SAS-2* data base (14), taking into account the instrumental energy response [for details see ref. (13)]. The value of N_H was estimated via the interstellar absorption derived from the Lick galaxy counts (15) assuming $N_H=2.9\times10^{21}\log(50/N_g)$ atom cm^{-2}, where N_g are the corrected galaxy counts.

3. Comparison of γ-ray flux and gas column density A relation of the form $I_\gamma=(q/4\pi)N_H+I_B$ was assumed, and the expected counts were obtained by convolving the quantity $E\times I_\gamma$ with the angular response of *SAS-2* (E is the sky exposure). In order to determine q and I_B for each energy range, a maximum likelihood method was applied on 25 sq. deg. bins [for details see ref. (4) and (13)]. The analysis has been restricted to galactic latitude $|b|>10$ deg.; The resulting q and I_B values are given in Table 1.

Table 1

Energy range (MeV)	35-100	>100
(All sky)		
$q/4\pi$ ($10^{-26}s^{-1}sr^{-1}$)	3.60±0.33	1.84±0.15
I_B ($10^{-5}s^{-1}sr^{-1}$)	9.70±0.56	1.92±0.21
(Loop I only)		
$q/4\pi$ ($10^{-26}s^{-1}sr^{-1}$)	6.22±1.00	2.06±0.29
I_B ($10^{-5}s^{-1}sr^{-1}$)	11.2±1.72	2.33±0.41
(Remaining sky)		
$q/4\pi$ ($10^{-26}s^{-1}sr^{-1}$)	2.29±0.31	1.67±0.16
I_B ($10^{-5}s^{-1}sr^{-1}$)	9.30±0.56	1.78±0.21

This analysis give the opportunity to map the regions of the sky where the observed γ-ray intensity I_γ^{obs} differs from the expected one: $I_\gamma^{exp}=(q/4\pi)N_H+I_B$. For each sky bin, we have computed in both energy ranges the excess intensity $\Delta I_\gamma=I_\gamma^{obs}-I_\gamma^{exp}$. Figure 1 gives, for each energy range, a map of the excess significance.

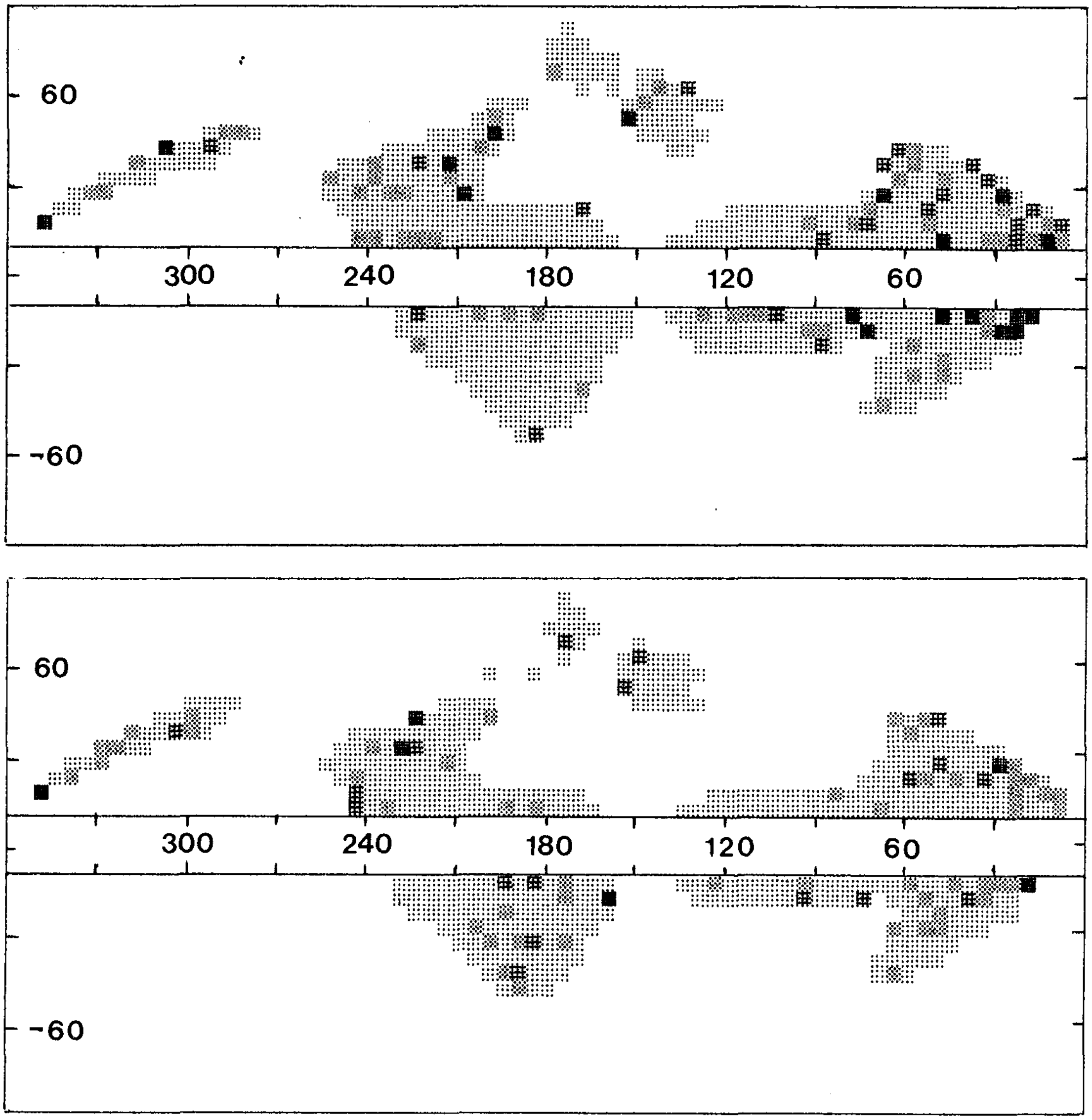

Figure 1. Galactic maps of the statistical significance S of the γ-ray intensity excess ΔI_γ (see text). The four tones of grey, from light to dark, refer respectively to $S<1\sigma$, $1\sigma<S<2\sigma$, $2\sigma<S<3\sigma$, $S>3\sigma$. Blank denotes regions not used. Upper map: $35<E_\gamma<100$ MeV; lower map: $E_\gamma>100$ MeV.

4. Discussion Our analysis does not modify the well admitted agreement between the predicted emission from total gas and the observed γ-ray intensity. However, the bins where the observed γ-ray flux are significantly in excess with respect to the relation $I_\gamma=(q/4\pi)N_H+I_B$ derived over the whole sky, seem to concentrate, particularly at low energy, in a wide region, which also contains the most prominent radio feature associated with Loop I.

In order to substantiate this impression, we have repeted our analysis in two distinct regions in the sky: (i) a roughly circular zone, of 70 deg. radius, coinciding with the radio profile of Loop I (16), and (ii) the remaining sky. The resulting q and I_B values are given in Table 1. The most striking result is the very large and significant ($\sim 3.7\sigma$) difference between the γ-ray emissivities q, measured inside and outside Loop I at low energy (35-100 MeV). At higher energies, the effect is only marginal. It should be noted that this difference in emissivity is not accompanied by a variation of the background estimates which are almost identical.

A similar γ-ray excess has been reported in the *COS-B* data (E_γ>70 MeV), for ℓ<50 deg. and b>10 deg. (5,17), but with no counterpart for b<-10 deg. and still clearly visible beyond 300 MeV. On the other hand, our result is qualitatively in agreement with that obtained by Bhat *et al.* (10), using the same γ-ray data base. We feel that a more detailed study of the structure of the excess, involving in particular the *COS-B* survey, is required to firmly confirm the rather attractive possibility of an enhanced CR intensity within the Loop I SNR, but this runs out the limitations of the present paper. However, it should be clear that the average γ-ray emissivity in the solar neighbourhood (2,4,5,13,17), and the inferred CR spectra (4,13,18) appear now rather meaningless, since significant variations are present.

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