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RADIAL DISTRIBUTION OF COSMIC RAY INTENSITY IN THE GALAXY FROM GAMMA-RAY DATA

A. Goned and A. Wahdan

Physics Department, Faculty of Science, Ain Shams University, CAIRO, EGYPT

ABSTRACT

The radial distributions of Galactic γ-ray emissivity and cosmic ray intensity are derived by unfolding the SAS2 line flux data. The results show a marked gradient, with the cosmic ray intensity in the region $3 < R < 7$ kpc being 3-4 times as much as locally. There is also an indication for a higher gradient for cosmic rays of lower energy.

1. Introduction

The gamma-ray line flux measured by SAS2 comes mainly from within the Galactic plane region ($|b| < 10°$). For energies $E_\gamma > 35$ MeV the main production mechanisms are the π° and bremsstrahlung processes with only a small contribution from Inverse Compton scattering. Therefore, the line flux measurements can be used to derive information on the radial distribution of nucleons and electrons in the Galaxy.

The usual technique used for deriving the large scale radial distribution of cosmic rays is to unfold the measured longitude dependence of gamma-ray flux (e.g. Strong, 1975, Issa et al, 1981). The resulting radial dependence of emissivity is then divided by the smoothed total gas density.

In the present work, we have used a modified method to unfold the line flux, assuming a Galaxy with cylinderical symmetry. The H_2 gas densities of Blitz and Shu (1980) are then used to find an estimate for the radial distribution of cosmic rays in the Galaxy.

2. The Unfolding Method

The radial distributions of gamma-ray emissivity are derived from SAS2 data for $E_\gamma > 35$ MeV and $E_\gamma > 100$ MeV. The distributions are obtained by unfolding the line flux integrated between latitudes of $-10°$ and $+10°$ for ℓ:0°-180°, and excluding known discrete sources.

Assuming cylinderical symmetry, the Galaxy with $Z_{1/2}$ = 115 pc has been divided into 16 concentric rings, with ring (j) having a mean radial distance from the centre of R = (j-1) kpc. The line flux data are then fitted to the following equation :

$$I(>E_\gamma, \ell) = \frac{(q_{\pi^\circ} + q_B)}{4\pi} \sum_j \varepsilon_j W_j(\ell) + I_{B.G.} \qquad (1)$$

where :

q_{π° and q_B are the local emissivities from the π° and bremsstrahlung processes, respectively, evaluated for a gas density of 1 H atom/cm^3,

ε_j is the relative γ-ray emissivity, assumed to depend only on R and is given by

$$\varepsilon_j = (G_j + \eta)\, F_{CR}(j) \qquad (2)$$

where G_j is the gas distribution function, normalized such that G(R=10 kpc) = 1 , η is the contribution of Inverse Compton process relative to the π°- and B-processes, and $F_{CR}(j)$ is the distribution of cosmic rays. In equ (1),

$$W_j(\ell) = \int_{-10^\circ}^{+10^\circ} \Delta r_j(\ell, b)\, db$$

represents the contribution of the jth ring to the line-of-sight integral, and $I_{B.G.}$ is the background flux. Table (1) gives the values of the parameters used in equ. (1).

Table (1)

E_γ (MeV)	$q_{\pi^\circ} + q_B$ (cm^{-3}s^{-1})	η	$I_{B.G.}$ (cm^{-2}s^{-1}rad^{-1})
> 35	2.82×10^{-25}	0.08	2×10^{-5}
>100	1.682×10^{-25}	0.05	3.5×10^{-6}

3. Results and Discussion

The radial distributions of relative emissivity are shown in Figs. (1a,b). The distributions of cosmic ray intensity, obtained by using the gas density distribution of Blitz and Shu (1980) are shown in Figs. (1c,d) for $E_\gamma > 35$ and > 100 MeV, respectively.

The results shown indicate marked gradients, with the cosmic ray intensity in the region $3 < R < 7$ kpc being 3-4 times that locally. A comparison of Fig. (1c) with Fig. (1d) also indicates a higher gradient for lower energy cosmic rays. The mean magnitude over R = 3-7 kpc is 3.67

for $E_\gamma > 35$ MeV compared to 3.06 for $E_\gamma > 100$ MeV, while the corresponding median electron energies are approximately 70 and 185 MeV, respectively (Goned, 1981).

Another feature that is apparent from the results is the existence of a minimum in both the emissivity and cosmic ray distributions at $R \simeq 9$ kpc. This corresponds to a dip in the longitude distribution of γ-rays near $\ell \simeq 60°$. Such minimum has been observed in the unfolding results of Issa et al, (1981) and is assumed to be the result of long path lengths through the inter-arm region between the Sagittarius and Orion arms.

In general, the results point strongly to the existence of cosmic ray gradients in the Galaxy. This could be an evidence for a Galactic origin for cosmic rays producing the γ-rays with the energies considered here.

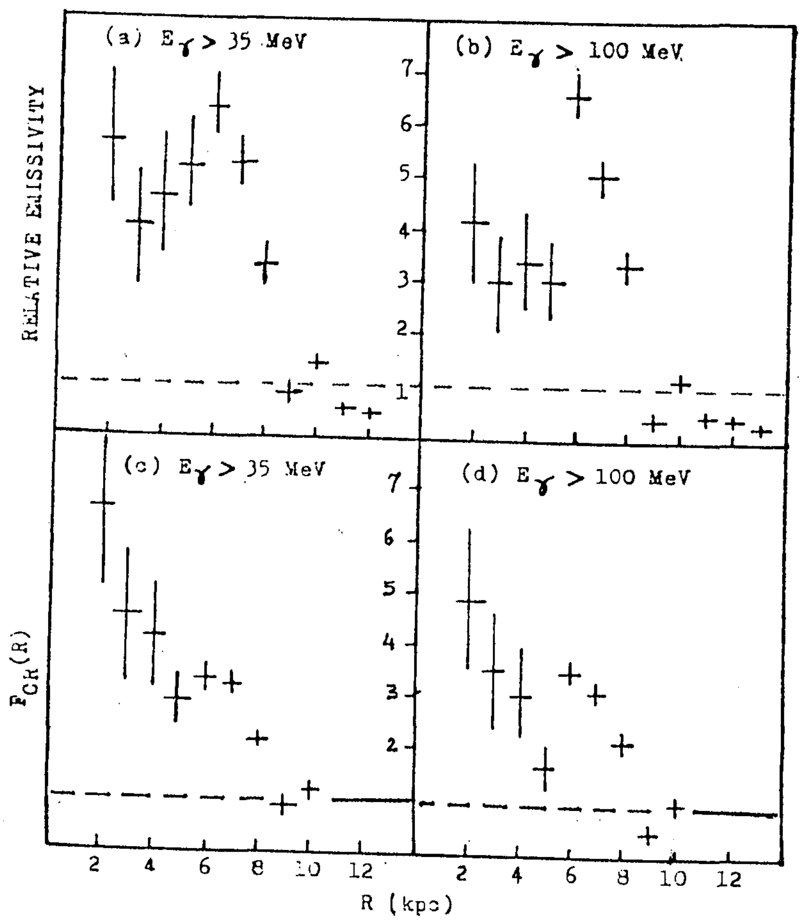

FIG. (1). RELATIVE EMISSIVITY AND COSMIC RAY INTENSITY DISTRIBUTIONS.

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