THE COMPONENTS OF THE GALACTIC γ-RAY EMISSION

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The galactic luminosity for $0.1 < E_\gamma < 2$ GeV can be evaluated directly from observational data and the commonly accepted value is $5\ 10^{38}$ erg s^{-1}. Various contributions to the γ-ray emission can be recognized, namely i) strong sources, ii) pulsars, and iii) diffuse processes. Their relative importance is discussed in the following.

A recent list of γ-ray sources (Caravane Collaboration, 1979) includes 29 entries, 3 of which have $|b|$ much larger than average and are disregarded here. The main features of the distribution are a strong concentration toward the galactic plane and a marked asymmetry between the regions inside and outside the solar circle. This property can be measured by the ratio $r = (N_i - N_o)/(N_i + N_o)$, with $N_{i,o}$ = detected sources having $-90° < \ell < +90°$ and $+90° < \ell < +270°$, respectively. To avoid biases deriving from different sensitivity at different longitudes, we retain only sources with flux $\geqslant \Phi_m = 1.1\ 10^{-6}$ ph cm^{-2} s^{-1} = $5.2\ 10^{-10}$ erg cm^{-2} s^{-1}. Thus, we obtain $N_i + N_o = 20$ and $r = .65$. Such high ratio, and the evolutionary constraints discussed by Panagia and Zamorani (1979) suggest a Pop I distribution $\exp(-\alpha R)$, with $\alpha = (2.2\ \mathrm{kpc})^{-1}$ and an inner cutoff at 5 kpc. Under the assumption that all the sources have the same luminosity L_γ, a second order expansion around the solar position gives

$$(N_i + N_o) = (\sigma_\odot/4\ \Phi_m)\ \{1+(1-1/\alpha R_\odot)(\alpha^2\ d^2/8)\}$$

$$r = (4/3\pi)\ \alpha d\ \{1+(1-1/\alpha R_\odot)(\alpha^2 d^2/8)\}^{-1}$$

here $\sigma_\odot$ = luminosity surface density at Sun due to the strong sources and $d^2 = L_\gamma/(4\pi\Phi_m)$. By integrating σ over the galactic plane with the same Pop I distribution, we find a source contribution of L(strong sources) = $(2.58 \pm 0.85)\ 10^{38}$ erg s^{-1}.

Another established class of γ-ray sources are the radio pulsars, including both very young objects and more typical ones with ages $\geqslant 10^5$ yrs. In order not to count twice strong sources, such as those associated with the Crab and the Vela pulsars, in the following we consider only the

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latter subclass. Thus, we can apply the findings of Buccheri et al. (1978) that the conversion efficiency from rotational energy loss $\dot{E}$ to γ-ray luminosity L_γ increases with age and is about unity for most objects. We use the radio data from Gullahorn and Rankin (1978) and Taylor and Manchester (1975); rather than $\dot{E}$ we calibrate $\dot{P}$ vs L_r, and convert it to $\dot{E} \equiv L_\gamma$ by means of the average P^{-3} and the standard moment of inertia 10^{45} g cm^2. The scatter diagram in the log L_r - log $\dot{P}$ plane appears as an approximately uniform distribution within a strip, whose upper and lower envelopes define $L_{\gamma max}$ and $L_{\gamma min}$ for any L_r. This result combined with the pulsars' radio luminosity function (Taylor and Manchester, 1977), uniquely determines their bivariate distribution as a function of L_γ and L_r. Integrating this distribution over the galactic plane with allowance for the limited observable bandwidth and the radio beaming factor (the γ beaming factor is irrelevant), the final result is L(pulsars) = (1.25 ± 0.50) 10^{38} erg/s.

The remaining fraction of the γ-ray luminosity may be then ascribed to cosmic-ray interactions with the interstellar gas. Current estimates indicate that π^0-decay is the only relevant mechanism for $E_\gamma > 0.1$ GeV, and its contribution to the galactic luminosity is

$$L(\pi^0) = L(\text{total}) - L(\text{strong sources}) - L(\text{pulsars}) =$$
$$= (M_g/m_p)\ s_\odot \ \langle f \rangle$$

where $M_g \approx 10^{43}$ g is the total mass of the interstellar gas (Mezger, 1978), m_p the proton mass, $s_\odot$ the energy yield in the solar neighbourhood ($\approx 5.5\ 10^{-29}$ erg/s), and $\langle f \rangle = \int f n_g\, dV \,/\, \int n_g dV$ is the ratio of the cosmic-ray density to the local value weighted with the gas distribution. So we are able to evaluate <f> ,and with $L(\pi^0) = (1.2 \pm 1.0)$ 10^{38} erg s^{-1} we obtain $\langle f \rangle = 0.1 - 0.6$. <f> can also be computed "a priori" by assuming a gas distribution and a relation between f and n_g. For example, using the data of Gordon and Burton (1976) and $f = n_g/n_\odot$ as suggested by Fichtel et al. (1976) gives $\langle f \rangle = 2.6$, much higher than the above value.Therefore, such a positive correlation of f with n_g can be excluded. Indeed, this provides evidence that π^0-decay emissivity is reduced in the high density regions.

References

Buccheri, R. et al. : 1978, Nature 274, 572.
Caravane Collaboration: 1979, Proc. 16th ICRC, Kyoto, 12, 36.
Fichtel, C.E. et al.: 1976, Astrophys. J. 208, 211.
Gordon, M.A. and Burton, W.B.: 1976, Astrophys. J. 208, 346.
Gullahorn, G.E. and Rankin, J.M.: 1978, Astron. J. 83, 1219.
Mezger, P.G.: 1978, Astron. Astrophys. 70, 565.
Panagia, N. and Zamorani, G.: 1979, Astron. Astrophys. 75, 303.
Taylor, J.H. and Manchester, R.N.: 1975, Astron. J. 80, 794.
Taylor, J.H. and Manchester, R.N.: 1977, Astrophys. J. 215, 885.