

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 $5 \cdot 10^{38}$ 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 $-90^\circ < l < +90^\circ$ and $+90^\circ < l < +270^\circ$, respectively. To avoid biases deriving from different sensitivity at different longitudes, we retain only sources with flux $\geq \phi_m = 1.1 \cdot 10^{-6}$ ph $cm^{-2} s^{-1} = 5.2 \cdot 10^{-10}$ 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 $\alpha = (2.2 \text{ kpc})^{-1}$ 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

$$(N_i + N_o) = (\sigma_o / 4 \phi_m) \{ 1 + (1 - 1/\alpha R_o)(\alpha^2 d^2 / 8) \}$$

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

here σ_o = 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 $L(\text{strong sources}) = (2.58 \pm 0.85) \cdot 10^{38}$ 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 $\geq 10^5$ 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

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 cm². 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 $L(\text{pulsars}) = (1.25 \pm 0.50) 10^{38}$ 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

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

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 ($\approx 5.5 \cdot 10^{-29}$ erg/s), and $\langle f \rangle = \int n_g dV / \int n_\odot dV$ is the ratio of the cosmic-ray density to the local value weighted with the gas distribution. So we are able to evaluate $\langle f \rangle$, and with $L(\pi^0) = (1.2 \pm 1.0) 10^{38}$ erg s⁻¹ we obtain $\langle f \rangle = 0.1 - 0.6$. $\langle f \rangle$ 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

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