GAMMA-RAY OBSERVATIONS AND THE LARGE SCALE STRUCTURE OF THE GALAXY

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Within the last few years, γ-ray astronomy has shifted from the discovery phase to the exploratory phase, thanks to the SAS-2 and COS-B satellites. The strongest feature of the γ-ray sky is the overwhelming emission of the galactic disc; even the radiation observed away from the galactic plane appears to be predominantly galactic, on the basis of its latitude dependence (Fichtel et al., 1978). Nevertheless, extragalactic γ-ray astronomy is not hopeless: the γ-radiation of the nearby quasar 3C273 has been very recently detected (Swanenburg et al., 1978). A brief summary of the present status of the galactic γ-ray astronomy follows.

1. LATITUDE AND LONGITUDE DISTRIBUTIONS

In their analysis of the COS-B data obtained during its first year of operation, Bennett et al. (1977) investigated in detail the latitude distribution of the γ-radiation. Figure 1 shows the observed width of the γ-ray disc as a function of the galactic longitude. The central regions are not resolved; this sets an upper limit of $\sim 2°$ on the width of the emitting region in the inner part of the Galaxy. At large angular distances from the galactic centre, the disc is resolved and appears quite broad, suggesting that a large fraction of the γ radiation is emitted close by. Furthmore, the asymmetry with respect to $b = 0$ points towards a local nature of the radiation from the outer disc, in agreement with the conclusion of Strong et al. (1977) that the γ-ray disc does not extend beyond the Perseus arm. Turning now to the inner regions of the Galaxy, Bennett et al. (1977) have derived more precise latitude profiles using only γ rays with $E \geq 300$ MeV, taking advantage of the better angular resolution of the COS-B instrument in this energy range. The latitude profile in the longitude range $10° \leq \ell \leq 40°$ reveals the presence of an additional component at low positive latitudes, possibly related to local dense clouds. This profile also exhibits a small displacement of the maximum emission towards negative latitudes, reminiscent of a similar asymmetry in the CO emission of the same region observed by Cohen and Thaddeus (1977).

W. B. Burton (ed.), The Large-Scale Characteristics of the Galaxy, 125 130.

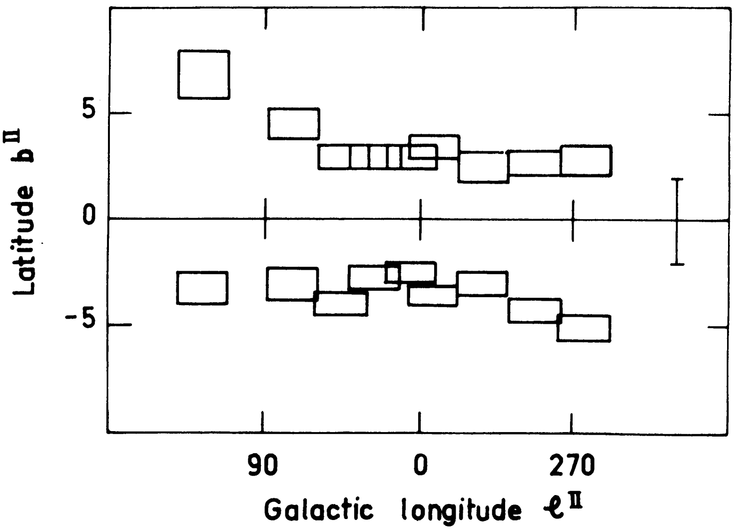

Figure 1. Variation with longitude of the latitude at which the -ray intensity (E $\geq$ 100 MeV) is half the maximum value. The error bar represents the F.W.H.M. for an ideal line source (it reflects the effect of the finite angular resolution of the instrument).

Figure 2 shows the distribution along the galactic equator of the γ radiation, obtained from the SAS-2 (Fichtel et al., 1977) and COS-B (Bennett et al., 1977) data. Note that the COS-B distribution is an average over successive observations not corrected for possible systematic effects. Both distributions are in remarkable agreement within uncertainties (10% to 30% of the quoted intensities). Small scale structures are discussed in detail by Hermsen et al.(1977), including 11 so far unidentified γ-ray sources, from the study of 1/3 of the galactic plane. Three sources of the COS-B catalogue (CG185-5=PSR0531+21, CG263-2=PSR0833-45, and CG195+4), were previously reported by the SAS-2 group (Kniffen et al., 1977a) as well as evidence for γ-ray emission from PSR1747-46, PSR1818-04 and Cygnus X-3, not yet confirmed by COS-B.

2. SPECTRAL CHARACTERISTICS OF THE GALACTIC GAMMA RADIATION

Paul et al. (1978) have presented the γ-ray spectrum relative to different regions of the Galaxy, in which sources may be present to a greater or lesser extent. It is premature to draw astrophysical conclusions before carefully subtracting the source contribution. However, in some regions the contribution of sources seen by COS-B appears quite small (less than 10% of the intensity above 100 MeV for $116° \leq \ell \leq 136°$).

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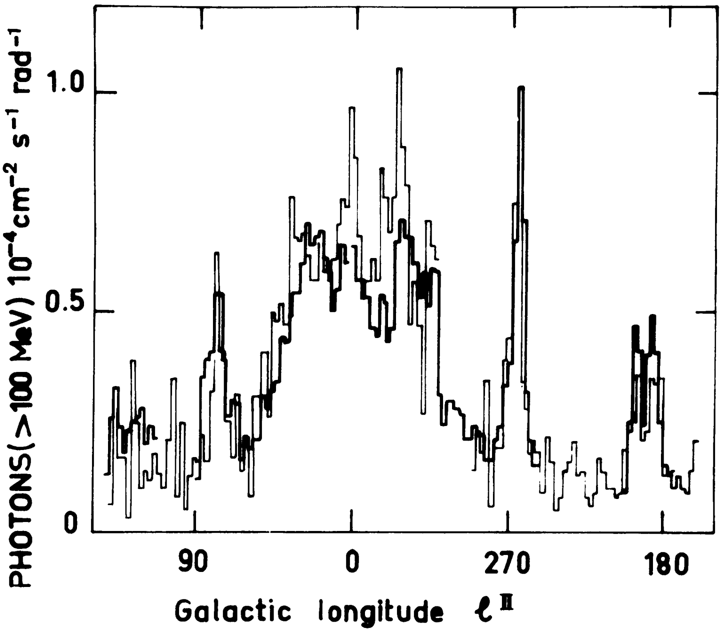

Figure 2. Longitude profile of the γ-ray intensity (E ≥ 100 MeV).
Thin line: SAS-2 data integrated over the latitude range $|b| \leq 5°$.
Thick line: COS-B data integrated over the latitude range $|b| \leq 6°$.

The source contribution seems also insignificant in the high latitude observations performed by the SAS-2 group (Fichtel et al., 1978). In both cases, the observed galactic γ radiation is presumably local, then its spectral characteristics provide some information on the diffuse emission in the local interstellar medium. The main emission mechanisms involve high energy nucleons ($\pi°$ induced emission) and electrons (Bremsstrahlung). Cesarsky et al. (1978) have recently evaluated the local production rate of very high energy photons. Fitting the spectrum of the local diffuse radiation from the galactic region $116° \leq \ell \leq 136°$ (Paul et al., 1978) and from regions away for the galactic plane (Fichtel et al., 1978) they conclude that the flux of cosmic-ray electrons (in the range 50 - 500 MeV) is much higher than that predicted by demodulation theories.

3. LARGE SCALE STRUCTURE OF THE GAMMA-RAY DISC

On the basis of the SAS-2 γ-ray observations, several authors (Kniffen et al., 1977b; Cesarsky et al., 1977; and references therein) have developed models in which most of the high energy γ radiation is of diffuse origin and should be a tracer of the galactic structure. However, the COS-B observations stress the importance of sources which

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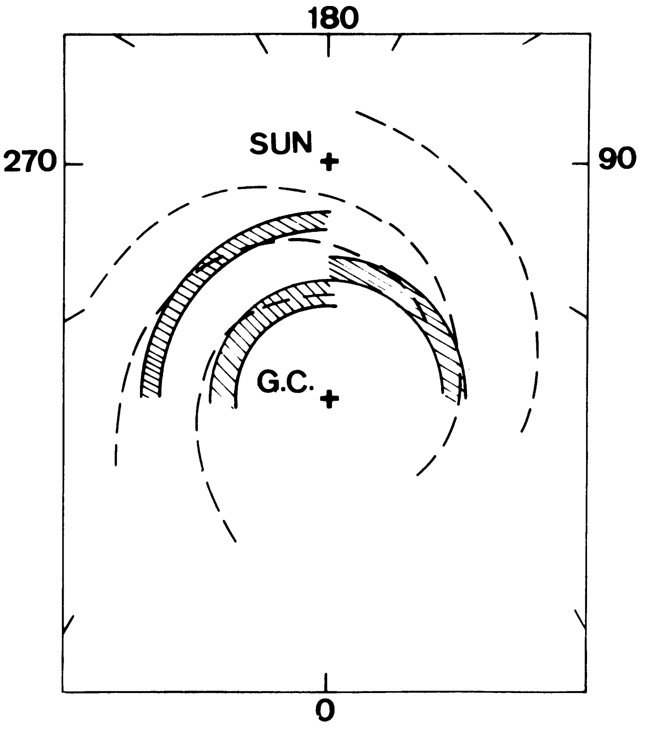

Figure 3. Repartition of high γ-ray emissivity regions across the galactic plane (shaded area) unfolded from the SAS-2 longitude profile, superimposed on the spiral pattern derived by Georgelin and Georgelin (1976). The regions of the galactic centre and beyond are excluded.

may contribute significantly to the overall γ-ray luminosity. In the anticentre region, for instance, they account for most of the emission. It seems now necessary to analyze the large scale structure of the γ-ray disc without any assumption regarding the physical origin of the galactic γ radiation.

This approach is attempted by Caraveo and Paul (1978) using the unfolding technique described by Strong (1975) which only implies the assumption of cylindrical symmetry (at least in one half of the Galaxy). This technique leads to distinct radial distributions of the γ-ray emissivity for "positive" longitudes ($0° \leq \ell \leq 180°$) and "negative" longitudes ($180° \leq \ell \leq 360°$). At positive longitudes, the broad peak at a distance R = 5 to 6 kpc from the galactic centre, is reminiscent of the distribution of interstellar matter and young objects as e.g. supernova remnants and pulsars (Stecker, 1977). At negative longitudes, two peaks clearly appear at R = 4 to 5 kpc and R = 7 to 8 kpc. The γ-ray Galaxy is sketched on Figure 3 after Caraveo and Paul (1978).

4. CONCLUSIONS

High energy γ-rays provide a new view of the Galaxy. The γ-ray disc seems as thin as the gaseous disc but it may not extend well beyond the solar circle; structural features are clearly apparent. The physical origin of the γ radiation from remote galactic regions remain questionable. If the contribution of sources is dominant, leaving a small room to diffuse processes, one would be forced to assume that either the interstellar density is overestimated (Cesarsky et al., 1977) or that the cosmic-ray density is strongly reduced in dense clouds. The latter hypothesis, discussed by Cesarsky and Volk (1977) is not supported by Lebrun and Paul (1978) on the basis of COS-B observations.

I thank Michel Cassé for useful discussions.

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DISCUSSION

Stecker: Could the outer "ring" or "arm" in your Figure 3 be accounted for by a point source in the southern hemisphere longitude distribution (GC 312-1)?

Paul: The observed longitude profile of the galactic emission in the region $300° < \ell < 360°$ can, in principle, be represented by a few sources (see Hermsen et al., 1977). Due to the limited angular resolution of the γ-ray detector, however, even a spiral arm segment can appear as a source.

Okuda: Is the observed latitudinal distribution intrinsic?

Paul: The 2° angular resolution of the present γ-ray detector is not sufficiently small to resolve the latitude distribution at $\ell = 0°$.