Comment on the Origin of the High Energy Diffuse γ-Ray Background

Dar and Shaviv [1] have suggested that the extragalactic γ-ray background (GRB) may be produced by the interactions of cosmic rays with gas in intergalactic space within groups and clusters of galaxies. They have also criticized the hypothesis that the background is a superposition of γ rays emitted by unresolved γ-ray blazars ("grazars"). We take issue with both of these points.

The most direct observational evidence against the cosmic-ray origin hypothesis comes from comparing the galactic and extragalactic diffuse spectra. Dar and Shaviv have argued that if their hypothesis is correct, the shapes of these spectra should be similar. Figure 1, based on recent EGRET measurements [2,3], shows that this is not the case. With the spectra plotted as energy per decade, the extragalactic spectrum is consistent with a flat power law. (In fact, the extragalactic spectra may be "concave," with a minimum near a GeV, as predicted by recent calculations for the grazar origin model [4].) On the other hand, the galactic spectrum is clearly convex, having a pronounced peak near an energy of a GeV. This feature is produced by an inflection point in the differential photon spectrum, caused by the pion decay γ-ray peak [5] at $E_\gamma = m_\pi c^2/2 = 67.5$ MeV when that spectrum is multiplied by E_γ^2 to get the spectrum in energy flux per decade. The galactic spectrum shown in Fig. 1 is an average over the inner Galaxy [2], which is the brightest region of the γ-ray sky, yielding very small error bars and a well defined shape. In contrast, Dar and Shaviv [1] show spectra for small regions of the Galaxy which have much larger error bars.

Other evidence from EGRET data also goes against the hypothesis of cosmic rays filling the space between galaxies in clusters and groups with an intensity equal to that in our Galaxy. The lack observed γ rays from the Small Magellanic Cloud (SMC), a member of the local group of galaxies which is only 50 kpc away, limits the cosmic-ray flux in this vicinity to less than about 1/5 of the galactic value [6]. Dar and Shaviv argue that magnetic fields could keep cosmic rays out of the SMC; however, the SMC is a young irregular system with no evidence for an ordered magnetic field which might keep cosmic rays out. We also note that γ-ray evidence for a radial gradient in the galactic cosmic-ray distribution, from both CGRO [7] and previous satellite measurements [8], indicates that the cosmic-ray density even immediately outside the galaxy is considerably lower than the local galactic intensity.

Dar and Shaviv have also stated that "it is difficult to see how the observed isotropic GRB can be produced by the highly beamed emission from blazars.... Such a GRB is expected to exhibit significant angular and time variability." However, the GRB from unresolved grazars would exhibit only small angular fluctuations [9], consistent with the EGRET data. Also, because of the large number of sources involved and the fact that only a small fraction of the unresolved sources which produce the GRB are expected to be in a flaring state [4], the time variability, averaged over typical two-week EGRET observing periods, is expected to be quite small.

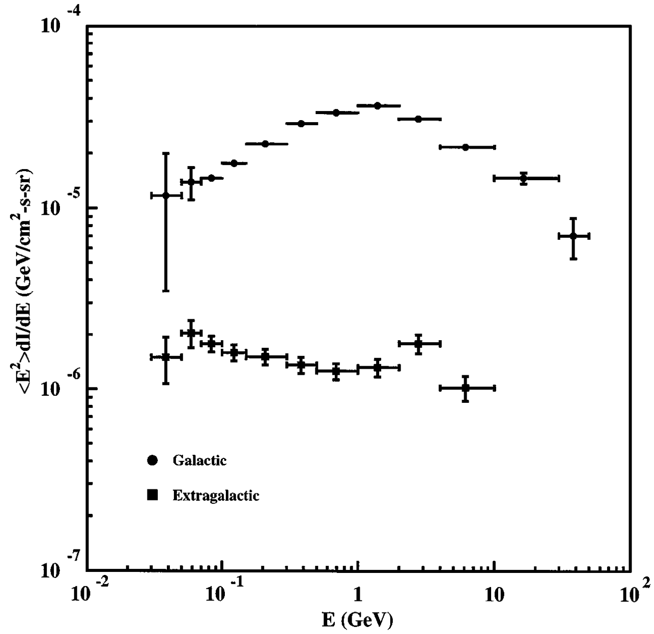

FIG. 1. Galactic [2] and extragalactic [3] γ-ray spectra.

Thus it is our contention that a cosmic-ray origin for the high energy GRB is ruled out by the existing γ-ray data; a grazar origin is consistent with the γ-ray data.

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