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ENHANCED GAMMA RAY FLUX FROM THE GENERAL DIRECTION OF THE VIRGO GALAXY CLUSTER

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ABSTRACT

There is an excess gamma flux from the general direction of the Galactic North Pole compared with that from the south when allowance is made for the contribution from CR interactions with the HI gas (Osborne et al., 1994). The extent to which it is in accord with the predictions of Wdowczyk and Wolfendale (1990 a,b) for gamma rays secondary to very high energy CR escaping from the VIRGO cluster is examined and it is claimed that the observations may well be of the order of those expected.

Key Words : gamma rays: interpretation - gas, galaxy clusters, cosmic rays.

I. INTRODUCTION

Most theories of the origin of cosmic rays involve the presence of extragalactic particles above 10^{18} eV or so. Certainly, if the majority are in fact protons then an extragalactic source seems inevitable. Many of the models involve active galactic nuclei (AGN) and insofar as the Virgo cluster is the site of one of the nearby strong AGN (M87) it might be expected that some of the detected ultra high energy particles (UHE) come from Virgo. There is some evidence from the arrival directions (e.g. Szableski et al., 1986) for an excess of UHE particles from that direction and Wdowczyk and Wolfendale, 1990a have designed a model to fit the facts. In this model UHE particles are generated by AGN within the Virgo cluster and diffuse away from it through the weak, irregular intergalactic magnetic field. Some of the particles then arrive at earth, albeit with directions only within some tens of degrees of Virgo.

A feature of the 'Virgo model' is the existence of a halo of gamma rays surrounding the cluster, these gamma rays having come from $p - \gamma_{CMB}$ interactions, and the ensuing cascade. In Wdowczyk and Wolfendale (1990b) they estimated the magnitude of this halo flux, using cascade calculations given by Strong et al. (1973) and other, more recent workers.

II. ANALYSIS OF THE COMPTON GRO DATA

(a) The General Method

Osborne et al. (1994) have recently analysed the CGRO data from the standpoint of deriving the intensity of diffuse gamma rays. The method adopted was the standard one of plotting the gamma ray intensity against column density of gas (N(H)) and extrapolating to N(H)=0. Instead of integrating over all longitudes, however, the analysis was made for each Galactic Quadrant separately and for each hemisphere. It was found that the slopes of the I_γ. N(H) plots varied from Quadrant to Quadrant indicating that the average cosmic ray intensity varies somewhat from place to place. This result is consistent with that found by Wolfendale and Zhang (1994) and Osborne et al. (1995).

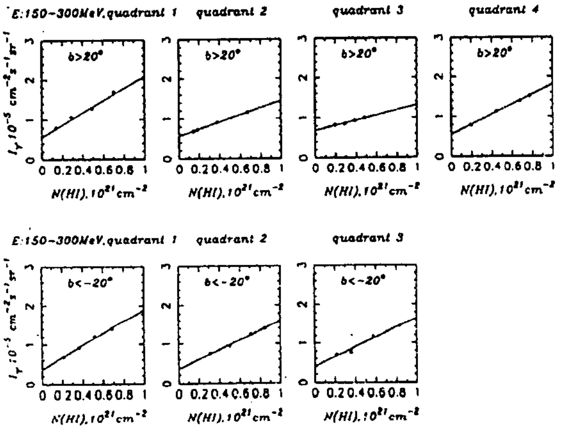

Fig. 1.— Gamma ray intensity versus column density of gas from the CGRO and gas column density measurements used by Osborne et al. (1994). The method of analysis, which involves use of the differences in intercepts between the Quadrants, is described in the text. Results for just one of the energy bands used are presented.

A prominent feature of the analysis was the appearance of an excess for the N Pole compared with that from the South. Virgo is at ℓ, b : 284°, +74° so that there is immediately the possibility, at least, of there being a Virgo halo. Figure 1 shows the result.

(b) Analysis by Galaxy Quadrant

This is the method described in §2.1 where I_γ is plotted against N(H). Figure 1 (from the data used by Osborne et al., 1994) shows such plots for some energy bands. The intercept is noted for each Quadrant and the difference between the sum of the values for Quadrant 3 and 4 and the sum for Quadrants 1 and

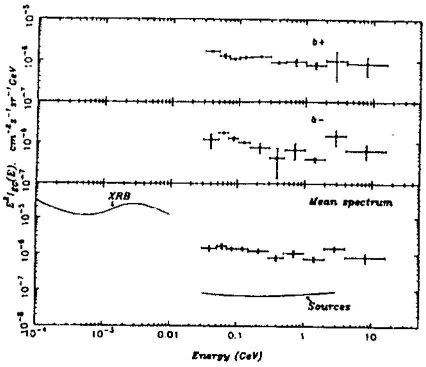

Fig. 2.— Extragalactic intensities derived separately for the two hemispheres and their mean value (Osborne, et al., 1994). It will be noted that the intensities for $b+$ are higher than those for $b-$.

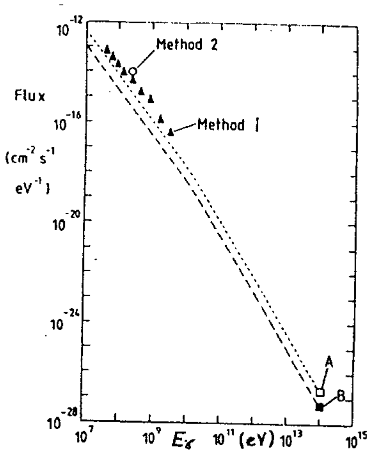

Fig. 3.— Estimated excess flux from the general direction of the VIRGO Cluster. The errors on the fluxes are typically ±30% for Method 1 and ±20% for Method 2. A and B (and their extrapolations to lower energies) are from the model of Wdowczyk and Wolfendale (1990 a,b).

2 is attributed to a Virgo halo. The mean excess over one steradian centred roughly on the Virgo position is plotted in Figure 3.

A similar analysis was carried out for the Southern hemisphere; this analysis yielded a zero result. It is apparent that the principle of the method is that the cosmic ray intensity is constant in each Galaxy Quadrant but can vary from one Quadrant to another. Although this cannot be proven it is a working hypothesis and the null result for negative latitudes gives some confidence.

A virtue of the method is that the Inverse Compton contribution, although quite large at high latitudes (Giller et al., 1994), should very largely cancel in the subtraction.

(c) Analysis on Smaller Angular Scales

The reasonably high statistical precision of the CGRO data allows an analysis on smaller angular scales, over which it is reasonable to assume that the cosmic ray intensity is essentially constant (but varying from 'cell' to 'cell').

The same gamma ray data were analysed in terms of RA and δ. Regions of width Δ(RA)=20° were taken of 10° intervals of declination, bracketing the Virgo direction. For each cell I_γ was plotted versus N(H) and the intercept for N(H)=0 was determined. The individual N(H)=0, gamma ray intensities were corrected for the I.C. intensity following the prescription of Giller et al. (1994) and the excess from the Virgo direction was determined. This analysis was carried out for $E\gamma > 100$ MeV and the corresponding differential intensity for $E_\gamma = 200$ MeV was determined; this value is shown in Figure 3.

Summed over one steradian centred approximately on the Virgo direction the two methods gives for the excess flux above 100 MeV: $(1.0 \pm 0.3)\ 10^{-5} cm^{-2} s^{-1}$ and $(2.0 \pm 0.4)\ 10^{-5} cm^{-2} s^{-1}$ respectively. The unknown systematic errors present in the analysis, are not too dramatic.

We conclude that there is some evidence (although not yet strong) for a Virgo gamma ray halo.

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