DIFFUSION OF HIGH ENERGY COSMIC RAYS FROM THE VIRGO CLUSTER

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The origin of the highest energy cosmic rays is unclear but the observation that many are seen to arrive from high Galactic latitudes supports the idea of Extragalactic sources. The characteristic features to be explained by any origin model are: the flattening of the energy spectrum above 10^{19}eV and the apparent presence of a directional anisotropy which increases systematically with energy.

Here we propose a model in which the particles above about 10^{18}eV are protons which are generated in galaxies in clusters and which diffuse in a tangled intergalactic magnetic field. Diffusion from

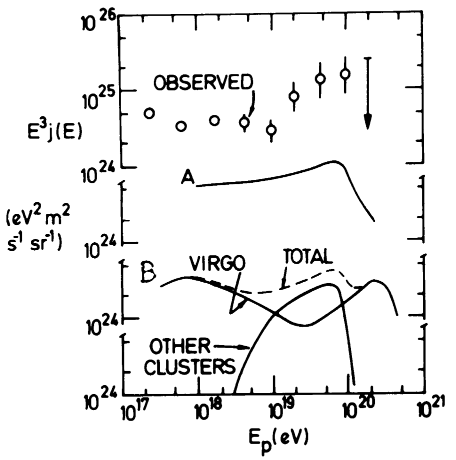

Figure 1. Primary cosmic ray spectrum. The observations are an average of data from Volcano Ranch, Yakutsk and Haverah Park (see Wdowczyk and Wolfendale, 1979 for references). The model predictions are: A Virgo cluster predominates, $D = 1.38 \times 10^{34} E_{19} cm^2 s^{-1}$
B Other clusters also contribute, $D = 3 \times 10^{35} E_{19}^{1.5} cm^2 s^{-1}$
(E_{19} is the proton energy in units of 10^{19}eV)

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non-uniformly distributed sources in the presence of interactions with the 2.7K radiation then generate spectra of the right general shape. If the diffusion coefficient is $\sim 10^{34} cm^2 s^{-1}$ at 10^{19}eV then the VIRGO cluster predominates but if D is higher by one or two orders other clusters will also contribute.

Figure 1 shows the measured energy spectrum and that as predicted. The energy input required for the VIRGO cluster is $1.38 \times 10^{25} E_{19}{}^{-2.17} s^{-1} GeV^{-1}$ (i.e. $\simeq 6.5 \times 10^{44}$ erg s^{-1} above 1 GeV). Such a value is somewhat higher than appears to be the case for our own Galaxy when scaled up to the mass of the cluster; this problem is removed if the spectral slope for VIRGO is a little less or if unusual galaxies (unusual from the Cosmic Ray standpoint) exist in VIRGO (M87?). In any event it is necessary to assume that the Galaxy is not producing Cosmic Rays above 10^{18}eV at the present time.

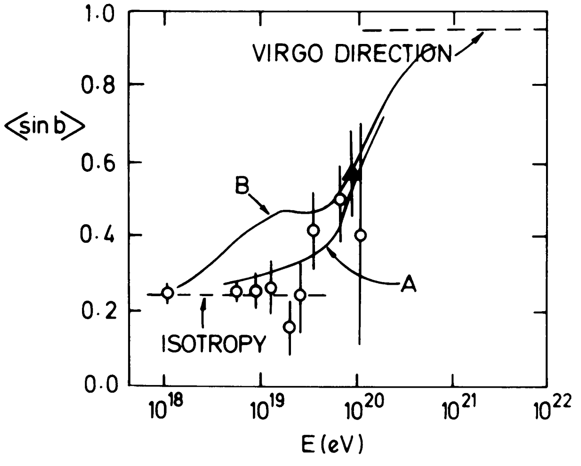

Figure 2. Anisotropy direction versus energy. The ordinate is the mean of the sine of the Galactic latitude of the arrival directions. O : Haverah Park expt. (Lloyd-Evans et al., 1979), Δ : Yakutsk (Krasilnikov, 1979). A and B as in Figure 1.

The models which fit the spectral shape also give a reasonable fit to the anisotropy results, although the latter may not be an accurate representation of the extragalactic anisotropy below about 10^{19}eV because of residual deflections by the Galactic field. Figure 2 shows the fit to the direction of the anisotropy; the fit to the amplitude is similarly reasonable.

References

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