

Observation of an Excess of Cosmic Ray Showers from the Direction of Centaurus A

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Abstract

An analysis of recent data from the Adelaide cosmic ray shower array suggests that an excess of events may have been observed to come from the general direction of Centaurus A. These data are presented and discussed together with directional data from other previous experiments.

1. Introduction

Cosmic rays which are detected through extensive air showers are generally believed to be high-energy nuclei. Our galaxy has a large-scale magnetic field which will deflect substantially all such charged cosmic rays (except perhaps those with energies above $\sim 10^{18}$ eV). It is not to be expected therefore that any distant source of cosmic rays would be detectable in a small region of sky which has an associated excess of events. Indeed, any deviations from isotropy which have generally been observed have been interpreted as a small excess of flux ($\lesssim 1\%$) from a very broad area of sky. This concept is built into the usual harmonic analysis of anisotropy.

It is usual, however, to check the data of an anisotropy experiment by using a chi-squared test on maps of sky intensity (see e.g. Chitnis *et al.* 1960). These tests are normally negative. We usually have no *a priori* reason for expecting a specific preferred direction and it is not surprising when one bin out of several hundred shows quite a large excess. We have carried out such an analysis for data from the Buckland Park air shower array (latitude 35°S) and find that in our case this largest excess happens to coincide with the direction of Centaurus A, our nearest neighbour active galaxy. We find some corroborative evidence in the literature for this observation.

2. Adelaide Observations

Our experimental work was carried out with the air shower array situated at the Buckland Park field station of the University of Adelaide. This sea level array has been described in detail elsewhere (Crouch *et al.* 1981) but, briefly, it detects cosmic ray showers with primary particle energies typically between 10^{15} and 10^{17} eV. The directional accuracy is of the order of $3^\circ \sec \theta$, where θ is the zenith angle of the shower. There can be substantial fluctuations in this directional error, particularly for lower energy showers. The array has a low energy threshold of about 10^{15} eV. The collecting area rises above this energy to $\sim 3 \times 10^4 \text{ m}^2$ for energies above $\sim 10^{16}$ eV.

our directional uncertainty) about Cen A, a chi-squared test gives a confidence level of $\sim 0.2\%$ for a chance occurrence. Fig. 1 shows the distribution of counts in the general direction of Cen A. The bins contributing mainly to the excess are in a NE-SW line.

We note also that if the data are split on the basis of shower size (a rough split in terms of primary particle energy), the NE-SW general feature persists but with poorer statistics.

We conclude that there is interesting evidence to associate Cen A with the arrival direction of an excess of cosmic rays of ~ 100 particles (of energy $\gtrsim 10^{15}$ eV) in 10^4 m² over a period of $\sim 7 \times 10^7$ s. This is more usefully expressed as about 3% of the cosmic ray background from the direction of the radio source Cen A. The confidence level of these data is not compelling. We have therefore examined the literature for other anisotropy studies at these declinations.

4. Other Anisotropy Studies

There are only two other studies which cover our declination range at about our energy and with reasonable statistics. These are the very early counting experiment at Auckland of Farley and Storey (1954), and a mu-poor experiment at Mt Chacaltaya in the 1960s (Kamata *et al.* 1968).

The most significant data of Farley and Storey (1954) correspond to energies of about 10^{15} eV. They relied on atmospheric collimation to give them a beamwidth of $\sim \pm 20^\circ$. The latitude of Auckland is such that Cen A passes through this beam. The results of this counting experiment show their most significant peak ($\sim 3\sigma$) at 14 h sidereal time, close to the direction of Cen A.

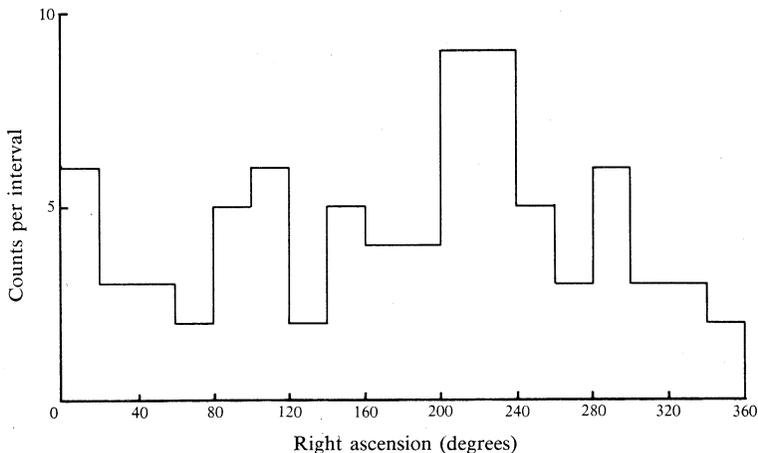


Fig. 2. Distribution of mu-poor showers detected at Mt Chacaltaya (Kamata *et al.* 1968) for declinations south of 30° S. The mean count per interval is 4.4 ± 2.1 .

The experiment at Mt Chacaltaya (Kamata *et al.* 1968) studied the arrival directions of a subset of all showers (with typical energies of 10^{15} – 10^{16} eV) which were apparently deficient in muons (mu-poor showers). This criterion was thought to be characteristic of photon initiated showers. The experiment accumulated a total of only 213 mu-poor showers, but summing all declinations showed a large peak (27 events) in the

R.A. range 200° – 220° (13·3–14·71 h) compared with an expected number of 13·8 events. Kamata *et al.* presented an arrival direction map of the sky; if we pick out the distribution of all events south of 30° S, we obtain the distribution in Fig. 2. There is a clear and significant excess in the direction 13·5–16 h. It may be worth pointing out that the zenith angles of these showers would have been quite large ($\geq 30^{\circ}$) and the directional accuracy probably poor.

The excess of events from each of the anisotropy experiments appears to be of the order of 1%–10% of the cosmic ray background in the appropriate direction. The Mt Chacaltaya data are difficult to interpret in this sense since extra selection criteria were employed based on an apparent deficiency of muons from the accepted showers.

It would seem that all three experiments which cover the area of the sky including Cen A suggest an excess of events from that general direction.

5. Discussion

Only three objects have been observed with reasonable statistical confidence at high γ -ray energies: these are Cen A (Grindlay *et al.* 1975*a*, 1975*b*), the Crab Nebula (Dzikowski *et al.* 1980; Boone *et al.* 1983) and Cygnus X-3 (Samorski and Stamm 1983), all of which in many ways are quite different objects. The Crab Nebula has been detected at $\sim 10^{15}$ eV using air shower techniques, particularly by looking for mu-poor showers. Cen A has been detected at energies lower by a factor of 10^3 using air Cerenkov techniques. There are good reasons for believing that the Crab Nebula would be at the limit of observable distances with 10^{15} eV γ rays since the microwave 3 K background photons are expected to have catastrophic collisions with such γ rays. These collisions are expected to have an interaction mean free path of only a few kiloparsecs (see e.g. Wdowczyk *et al.* 1971). The Crab Nebula is ~ 2 kpc from us, whilst Cen A is ~ 5 Mpc distant, and it would appear that if the present observations are causally related to Cen A, then their interpretation will not be straightforward. It may be necessary to invoke high-energy neutrinos or secondary γ rays from undeviated high-energy protons from Cen A which interact in the vicinity of our own galaxy.

In conclusion, there seems to be accumulated evidence from a number of experiments for an excess of cosmic ray showers from the general direction of Cen A with a directional distribution apparently related to the source structure. An interpretation of these data in terms of a high-energy photon flux from Cen A appears to be unacceptable due to the interaction of such photons with the microwave background.

Note added in proof: Preliminary results from a new air shower array at the University of Sydney (Luorui 1983) indicate a small peak for the declination band -30° to -40° at a direction close to that of Cen A discussed in the present paper.

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