LETTERS TO THE EDITOR

ASTRONOMY

An Experimental Test of the Mechanism of Radio Emission from Cosmic Ray Showers

THE suggestion by Askaryan[1] that a detectable radio pulse should be emitted by an extensive air shower was based on the coherent emission from a negative charge excess in the shower front. A more detailed analysis by Kahn and Lerche[2] showed that a radio pulse may also be emitted by the transverse current in the shower front which results from separation of charges in the Earth's magnetic field. Using a restricted model of the shower, consisting of a ring of charges, they showed that the radiation resulting from separation of charges would be expected to dominate over that from an excess of charges.

Radiation from separation of charges would be polarized perpendicular to the Earth's magnetic field, while that from an excess of charges would be polarized radially from the shower centre. Measurements of radio polarization have been obtained by Jelley *et al.*[3], and by Allan and Jones[4], who found no clear evidence for an east–west polarization, and by Borchovski *et al.*[5], who claimed to have found statistical evidence in favour of it.

A further test of the relative importance of the effects of the geomagnetic field and the separation of charges is to compare the magnitudes of pulses radiated by showers travelling along and perpendicular to the Earth's magnetic field. We have therefore compared the radio pulses received in identical aerial systems directed to the north and south at Jodrell Bank, where the dip angle is 68°. The aerials were corner reflectors two wavelengths long, with a beam-width of 45° directed at 45° to the zenith. The receiving equipment and the Geiger–Müller counters used to detect the shower front were similar to those used in the original detection of the radio pulses, except that further counters were added to form seven equilateral triangles extended along an east–west line 175 metres long. This line also contained the aerials, mounted back-to-back 29 m from the centre. Coincidences were registered whenever the three counters of any one triangle were simultaneously struck, and the two receiver outputs were then photographed. About eight coincidences per hour were obtained with this system, which corresponds to a threshold energy of about $5 \cdot 10^{15}$ eV.

The analysis consisted of recording the pulse heights in a channel centred on the expected position on the oscilloscope time base, with a width corresponding to the measured time jitter of $\pm 0 \cdot 5$ μsec which resulted from the variable delay in the Geiger–Müller counters. A reference channel 10 μsec later was also analysed in the same way. The results of this analysis are presented in Table 1 as the number of pulses in each channel the amplitude of which exceeds one of three specified levels, increasing by 6 decibels in peak power.

We note that there is a consistent excess of large pulses in the two signal channels but that there is no evidence of any difference between the north and the south channels.

Table 1

Level	1	2	3
South signal channel	210	38	2
North signal channel	247	36	1
South signal – south reference	41	17	2
North signal – north reference	43	14	1

Although the statistics are poor, it is already clear that radio pulses arriving across the lines of the geomagnetic field are not usually stronger than those which arrive along them. The expected ratio of the numbers in the lower two rows of Table 1 is about 7 : 1 if the shower numbers vary as $\cos^7$ (zenith angle) as recorded by Macleod[6] and the radio pulses wholly arise from the effects of the geomagnetic field. We must therefore conclude that the effects of the separation of charges do not dominate as Kahn and Lerche suggest they do. One possible explanation of this discrepancy between theory and observation is that the showers contain a higher excess of charges than was suggested by Askaryan, consisting, perhaps, of electrons of lower energy than those normally recorded experimentally.

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A Galactic Discontinuity at $l^{\text{II}} = 140°$

THERE is substantial evidence of a major discontinuity in the structure of the Galaxy at $l^{\text{II}} = 140°$. This evidence is provided by large changes in the numbers of Wolf–Rayet stars, dust-embedded stars and interstellar globules, in the wavelength dependence of the position angles of interstellar polarization of starlight, and in the orientation of the polarization vectors of galactic radio waves on each side of that longitude.

The Wolf–Rayet stars provided the first evidence of the discontinuity. It was pointed out by Vorontsov-Velyaminov[1], and confirmed by Roberts[2] and by Stephenson[3], that the anticentre region from $l^{\text{II}} = 140°$ to $l^{\text{II}} = 225°$ is completely devoid of Wolf–Rayet stars (Fig. 1*a*).

Hoffleit[4] and Blanco and Williams[5] discovered groups of stars in which the brightest are the most heavily reddened, apparently by circumstellar obscuring clouds. A survey by Reddish[6] has shown that such dust-embedded stars occur in a considerable number of associations and very young clusters, but that none of these are in the range of galactic longitudes from $l^{\text{II}} = 136°$ to $l^{\text{II}} = 253°$ (Fig. 1*b*). In addition to this general relationship with the distribution of Wolf–Rayet stars there is a more detailed relationship in that Wolf–Rayet stars are most often found in systems containing dust-embedded stars.

Estimates of the masses of interstellar globules, of the circumstellar clouds around dust-embedded stars, and of the shells around Wolf–Rayet stars, show that the masses are similar and of the same order as those of early type stars[6].

These observations support the views that massive stars form from globules and that Wolf–Rayet stars are very young objects in the last stages of contraction to the main sequence. They indicate that the region from $l^{\text{II}} = 140°$ to $l^{\text{II}} = 250°$ is not at present active in the formation of massive new stars.