LETTERS TO THE EDITORS

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A Lunar Effect on Cosmic Rays ?

As reported in previous communications, hourly records of cosmic ray intensity have been made in London during the past few years by registering threefold coincidences between three trays of Geiger-Müller counters.

The harmonic analysis of the average solar daily inequalities for the period May 1941–April 1944 revealed, besides the well known 24-hour wave, the existence of a physically significant semi-diurnal variation, S_c, nearly opposite in phase to the semi-diurnal oscillation of the barometer, S_p :[1]

$$S_c = 0\cdot14 \sin (2t - 6^\circ) \text{ in percentages of the mean,}$$
$$S_p = 0\cdot22 \sin (2t + 144^\circ) \text{ in millimetres of mercury,}$$

where t represents the measure in angle of Greenwich mean solar time. It was also found that the seasonal changes of these two waves follow each other closely.

Taking into account that the solar semi-diurnal oscillation of the atmosphere is partly tidal in character, these results led me to conclude that the semi-diurnal variation of cosmic-ray intensity could be explained by the motion up and down of the meson-producing layer, which is in phase with the atmospheric oscillation. It would be sufficient for this oscillation to be about ten times greater in the region where mesons are formed than at sea-level. (This point has been discussed more fully in my Guthrie Lecture.)

In the light of these results, it was thought of interest to ascertain whether the lunar atmospheric tide has any appreciable effect on the intensity of cosmic rays. To ascertain this, the data for 856 complete days of the period mentioned above have been used. The total number of coincidences recorded during this number of days amounts to 550 millions. From these data, following the method developed by Chapman and Miller[2], a lunar semi-diurnal variation of the cosmic ray intensity, L_c, is found which is expressed by

$$L_c = 0\cdot023 \sin (2\tau + 160^\circ) \text{ in percentages of the mean,}$$

where τ denotes Greenwich mean lunar time in angle. The probable error is 0·011 per cent, half that of the amplitude. Thus this variation might be regarded as physically significant, although the present determination is not very accurate.

If we take L_c as real and assume that it is due to the vertical motion of the meson-producing layer in phase with the lunar tide, then from the ratio

$$(S_c/L_c)_{\text{amplitude}}$$

which is equal to 6, we conclude that in the region where mesons originate the solar oscillation is six times greater than the lunar tide. Since the lunar tide for Greenwich at ground-level is, as determined by Chapman,

$$L_p = 0\cdot009 \,(2\tau + 114^\circ) \text{ mm. mercury, then } (S_p/L_p)_{\text{ampl.}} = 24.$$

Consequently, $L_c/L_p = 4S_c/S_p$, that is to say, the lunar tide must increase with height more quickly relatively than the solar oscillation.

This implication accords with results obtained by other means. Pekeris[3] has found from this theory that the vertical motion of air particles due to the solar oscillation in the ionosphere should be 130 times greater than at sea-level, while Appleton and Weekes[4] found experimentally a lunar tide in the Kennelly-Heaviside layer of the order of 1 km., which is 7,000 times greater than the tide at the ground.

Again, the fact that L_c is less than S_c, while the lunar tide in the ionosphere appears to be several times greater than the solar oscillation, indicates that mesons originate well below that region, a result also in accordance with present views.

It is therefore possible that the moon, by altering the height of the meson-producing layer, appreciably affects the intensity of cosmic rays as measured at the ground.

A more detailed account of this investigation will be published shortly.

A. DUPERIER.

Department of Physics,
Imperial College of Science and Technology,
South Kensington.
Nov. 8.

[1] Duperier, *Proc. Phys. Soc.*, 57, 464 (1945).
[2] Chapman and Miller, *Mon. Not. Roy. Ast. Soc., Geophys. Supp.*, 4, 649 (1940).
[3] Pekeris, see Appleton and Weekes (ref. 4, p. 186).
[4] Appleton and Weekes, *Proc. Roy. Soc.*, A, 171, 171 (1939).

Cosmic Ray Absorption Underground

As part of our cosmic ray programme, we had occasion to measure the absorption in lead of the radiation in a vertical direction on Holborn Underground Tube Station during the years 1937–39. While this work was going on, results of similar measurements underground were published by other workers[1]. Our work was left unpublished due to the pressure of war activity, but in view of the fact that very few measurements have been made underground, we think the results obtained are worth recording.

Thanks to the co-operation of the London Passenger Transport Board, the measurements were performed in a tunnel, 30 metres under London clay. The general layout of the apparatus with respect to the surroundings is shown in Fig. 1, which shows a telescope of four Geiger–Müller counters on a table, standing on a platform in the tunnel.

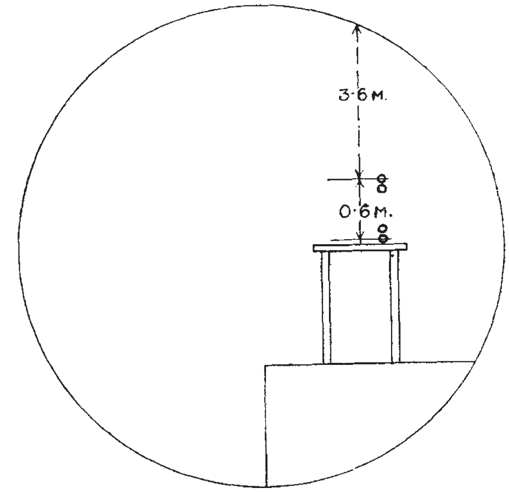

Fig. 1. DISPOSITION OF ABSORPTION COUNTER ARRANGEMENT UNDERGROUND. COUNTERS 3 CM. × 40 CM.

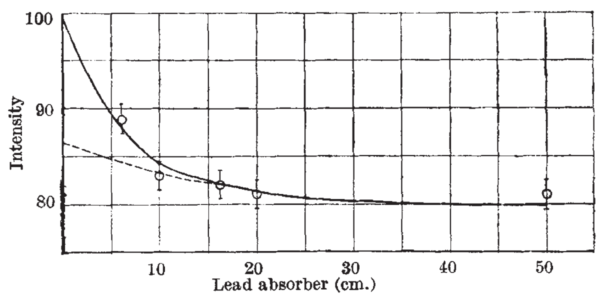

Fig. 2.

The absorption curve obtained is shown in Fig. 2, the dotted curve being the extrapolation of the hard component back to zero thickness. The amount of soft component thus deduced is 14 per cent, and the mass absorption coefficient of the hard component is found to be $1\cdot5 \times 10^{-4}$ cm.^{2}/gm.

While the results of all workers on the absorption coefficient may be regarded as mutually consistent, the same cannot be said of the proportion of soft component. Results for the soft component measured underground have varied from 5 to 25 per cent of the total intensity. This wide variation is due to differences in the geometry of the apparatus of the various workers ; and it is felt that before any assessment of this factor can be made, it is necessary that the arrangement of the apparatus be given, if possible, for the previous work, and certainly for any future measurements that may be made.

E. P. GEORGE.

Birkbeck College,
University of London,
London, E.C.4.
Nov. 29.

[1] Morgan and Nielsen, *Phys. Rev.*, 54, 245 (1938). Wilson, *Phys. Rev.*, 53, 337 (1938). Auger, *J. Phys.*, 6, 253 (1936).

Cosmic Radiations at 5 Metres Wave-length

THE discovery of electromagnetic 'noise' radiations at radio frequencies was first made by K. G. Jansky[1] who, in a series of measurements at about 20 Mc. s. ($\lambda \simeq 15$ m.) was able to establish the close connexion between the direction of greatest intensity and the centre of the galaxy. G. Reber[2] later made measurements at 160 Mc./s. ($\lambda \simeq 2$ m.), and he was able, by virtue of a narrower beam, to detect a number of subsidiary peaks. He found the intensity of radiation at this higher frequency was very much less ; he also suggested a probable explanation of the radiations, namely, the interactions in encounters between positive ions and free electrons released from interstellar gases by the photo-electric action of stellar radiations. The theoretical treatment for radiation arising from such encounters was first given by H. A. Kramers[3] to account for continuous radiation in X-ray spectra. The cosmic noise radiation is not observable at frequencies lower than a few megacycles per second, owing to the screening action of the ionosphere.

It appears important from the point of view of both astronomical and radio research to determine the distribution and intensity of the source in detail at various frequencies. The main practical difficulty is that, unless an unwieldy aerial system is used, the cosmic-noise power received is small compared with receiver noise at short wave-lengths of the order of 1 m., while at longer wave-lengths of the order of 10 m., the beam width is too wide for accurate study of the distribution. A compromise between these two factors has