LETTERS TO THE EDITORS

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Audio-Frequency Radio Waves from the Sun

THE recent discovery of solar radio noise, in the range 30–1,000 megacycles, raises the question whether lower frequencies may not also exist. Variable magnetic fields exist on the sun and probably in the stars as well. Small and rapid pulsations of spot fields may well occur, even though detection of the variations, by studies of the Zeeman effect, will prove difficult. Nevertheless, we may expect that these changing fields will produce electromagnetic radiations the maximum wave-lengths of which are comparable to stellar dimensions. Such low-frequency radiation will escape from the sun in the presence of a steady magnetic field, like those found in sunspots.

Partial absorption of such waves in the solar atmosphere may produce the observed high excitation of chromosphere, prominences and corona. In the earth's atmosphere, similar absorption may be responsible for the luminosity of the night sky and, possibly, also for the aurora polaris. The concentration of the latter in a zone near the magnetic poles may arise from the tendency of accelerated ions to spiral around the lines of magnetic force.

To explain the observed terrestrial effects as the action of solar electromagnetic waves, we require voltages of the order of 0·01–1·00 volts per cm. We postulate the existence of frequencies in the range of from 1 to, say, 500 cycles per sec., though the extent of the range is unimportant for our argument. These long waves will be diffracted around the earth and hence may well cause effects on the dark, as well as on the sunlit, hemisphere. With these assumptions, one readily calculates that an amplitude of at most several gauss, with the appropriate frequency, in the field of a spot can produce the desired radiation.

The total energies involved in the radiation are roughly equivalent to that from an area of normal photosphere about equal to that of a spot. Hence, we further suggest that the emission of radio energy provides a simple mechanism for cooling the spot.

The long-wave emission may account for many ionospheric phenomena, such as sporadic E. The waves will cause any 'seed' ionization to spread—a sort of multiplier effect. Some phases of ionospheric storms may also be explained as due to heating of the layers by the absorbed radiation. The waves will have a similar action on meteor trails, the growth and persistence of which are difficult to explain in terms of the meteor itself. The voltages and wave-lengths are sufficient to produce, in regions of low density, high-energy particles, like the softer components of cosmic rays. We suggest that the phenomenon here discussed may be the source of cosmic rays. We suppose that the harder components arise in stars the magnetic variations of which are much more intense than for the sun.

The suggestions made above demand experimental verification. As a first step in the study, we have constructed a large loop antenna, connected to a tunable audio amplifier. With this device, we have detected the existence of variations of the order of magnitude herein suggested, and of frequencies from 25 cycles (the lowest limit of the amplifier) to about 400 cycles.

Further experiments are in progress to determine whether we can attribute the effects to electromagnetic waves of solar origin, or whether we must assign them to micropulsations of the earth's magnetic field.

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Showers of Penetrating Particles

THE intensity of several 'components' of the cosmic radiation varies with atmospheric depth more rapidly than the intensity of the so-called total radiation (curves of Pfotzer and Millican): for example, showers of penetrating particles measured with a counter arrangement vary according to an exponential law $e^{-x/d}$, where x is the atmospheric depth in gm./cm.^{2} and $d \sim 100$ gm./cm.^{2} [1]. The cross-section for the collision of a primary shower-producing particle with a nucleus in air is of the order $2 \cdot 5 \times 10^{-25}$ cm.^{2}. Neutrons, protons, multiple nuclear disintegrations, large bursts and slow mesons show similar rapid decrease with increasing depth.

The present remarks will chiefly refer to the showers of penetrating particles. Some of them contain at least four particles each penetrating 20 cm. lead, as we have observed by means of eight-fold coincidences between eight counters arranged in four telescopes scattered on an area of 4 m.^{2}. Each counter was surrounded on all sides by 10 cm. lead. The frequency of these showers in S. Paulo (altitude 800 m.) was 3×10^{-4} min.$^{-1}$. Examination of experimental data on the density of particles in such showers, the existence of penetrating particles in extensive showers and the variation of meson intensity and spectral distribution at high altitudes (and at great depths) leads us to the following conclusions: the majority of mesons are produced in groups (in collisions of primary protons or secondary protons and neutrons with nuclei), with a multiplicity increasing with energy in accordance with the scheme suggested by us earlier[2].

Here we limit ourselves to the discussion of one argument. There is a striking difference between the slow variation with atmospheric depth of the frequency of single penetrating particles (chiefly mesons) as measured by a telescope (curves of Schein, Jesse, Wollan and of Ehmert), and the rapid exponential variation with depth of the frequency of penetrating showers measured by us[1]. Obviously, a telescope indicates the arrival of every meson the trajectory of which lies inside the solid angle defined by the counters. The collision process which gives rise to these mesons can take place at great altitudes above the telescope (for example, at 20 km. above), provided their life-time is long enough and their energy is not too low. Thus the telescope measures the integral intensity of mesons produced inside the solid angle defined by the telescope, whereas the large-angle arrangement of 4-fold or 8-fold coincidences used by us can only register bunches of particles created locally at distances of not more than a few hundred metres above the arrangement. Indeed, if, for example, the centre of the shower is located at 10 km. height above the arrangement, the angular spread of