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# The cosmic radiation*

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Coming out of space and incident on the high atmosphere, there is a thin rain of charged particles known as the primary cosmic radiation. As a result of investigations extending over more than 30 years, we now know the nature of the incoming particles, and some, at least, of the most important physical processes which occur as a result of their passage through the atmosphere.

Today the study of the cosmic radiation is, in essence, the study of nuclear physics of the extreme high-energy region. Although the number of incoming particles is very small in comparison with those which are produced by the great machines, most of them are much more energetic than any which we can yet generate artificially; and in nuclear collisions they produce effects which cannot be simulated in the laboratory. The study of the resulting transmutations is therefore complementary to that which can be made at lower energies with the aid of the cyclotrons and synchrotrons.

For the investigation of the cosmic radiation, it is necessary to solve two principal technical problems: First, to detect the radiation, to determine the masses, energy and transformation properties of the particles of which it is composed, and to study the nuclear transmutations which they produce. Second, to develop methods of making such observations throughout the atmosphere and at depths underground.

For the detection of the radiations, the same devices are available as in the general field of nuclear physics, and two main classes can be distinguished.

In the first class are found the trigger mechanisms such as the Geiger counter and the scintillation counter. Such devices record the instants of passage of individual particles through the apparatus. Their most important advantages are (a) that they allow observations to be made of great statistical weight; and (b) that the relationship in time of the instants of passage of associated particles can be established. With modern instruments of this type, the time interval between the arrival of two charged particles can be

* The lecture was illustrated by lantern slides and a film of the construction and launching of balloons.

measured even although this is as small as one or two hundredths of a microsecond. These devices have made possible contributions of the greatest importance to our knowledge of the subject, and they have proved especially valuable when the nature of the physical processes being studied has been well understood.

In the second class of detectors are the devices for making manifest the tracks of particles; namely, the Wilson expansion chamber and the photographic plate. These instruments have the particular advantage, amongst others, that they allow a direct and detailed insight into the physical processes which accompany the passage of charged particles through matter. On the other hand, it is arduous to employ them to obtain observations of great statistical weight. The two classes of instruments thus provide complementary information, and each has made a decisive contribution.

The second principal technical problem to be solved is that of making experiments at great altitudes. Some information has been obtained by means of V-2 rockets which pass almost completely out of the earth's atmosphere, but their time of flight is restricted to only a few minutes. Alternatively, balloons can be made to ascend to great altitudes and to give level flights for many hours. The simplicity of the photographic method of recording the tracks of charged particles makes it very suitable as a detector in such experiments.

Today the most suitable types of balloons for experiments on the cosmic radiation are those made of thin sheets of a plastic material, « polyethylene ». Although rubber balloons can sometimes be made to ascend higher into the atmosphere, their performance is erratic. The rubber, whether natural or synthetic, appears to perish rapidly under the action of the solar radiation high above the clouds: it is therefore difficult, even when employing many rubber balloons in a single experiment, to secure the sustained level flight which is desirable. On the other hand, polyethylene is chemically inert, and the fabric of the balloon can remain for many hours at high altitudes without any serious effect on its mechanical strength.

In Bristol, we construct balloons of polyethylene by methods similar in principle to those developed in the U.S.A. by the General Mills Corporation. We employ polyethylene sheet 1½ thousandths of an inch thick, the shaped pieces of which are « heat-sealed » together to form an envelope which, when fully inflated, is nearly spherical in form. Unlike those of rubber, these balloons are open at the lower end; and just before launching, the envelope is very slack and contains only a small fraction of its total volume filled with

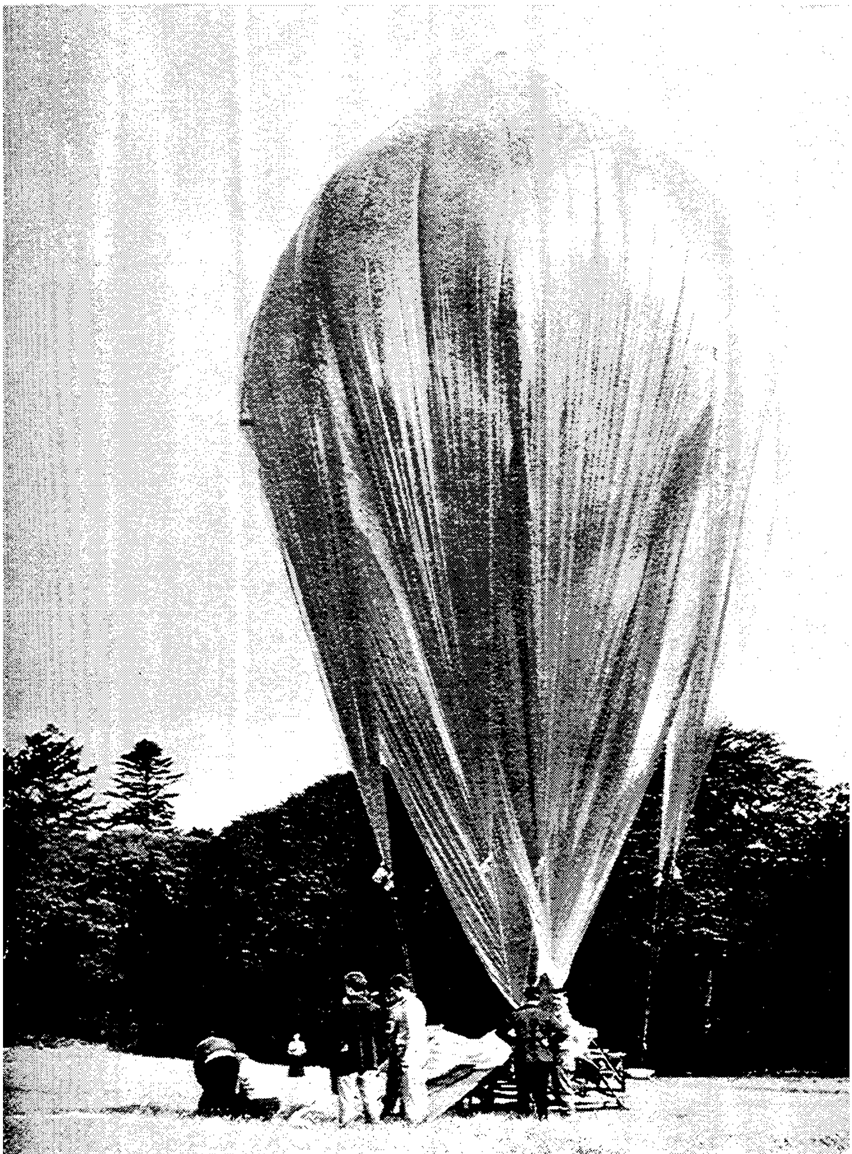

Fig. 1. Inflation of balloon of polyethylene just after dawn. The balloon has a total length of about 120 ft. and most of the fabric is on the ground. Such a balloon can in favourable conditions give level flight at about 90,000 ft. for many hours with a load of 40 kg.


Fig. 2. Examples of the tracks in photographic emulsions of primary nuclei of the cosmic radiation moving at relativistic velocities.

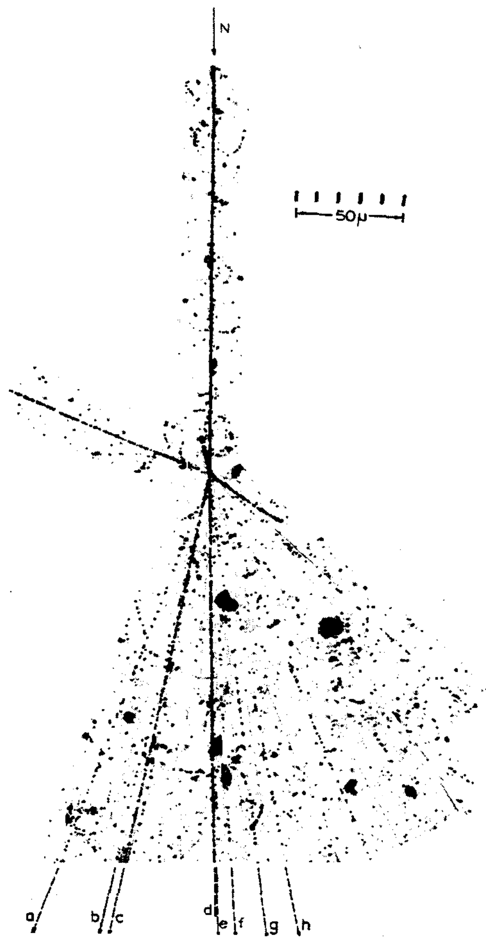


Fig. 6. A nitrogen nucleus of the primary cosmic radiation collides with a nucleus, and splits up into a lithium nucleus, a deuteron, and a number of protons. Some π-mesons are created in the collision. The event is very exceptional in that, by chance, the tracks in the emulsion of many of the particles are long so that they can be identified and their energy determined. *Top: N,* $\bar{\alpha}$ *= 0.0061 ~ 16%, 28,000* MeV. Bottom: (a) α-particle, $\bar{\alpha}$ = 0.109 ± 12%, 220 MeV; (b) π-particle, $\bar{\alpha}$ = 0.035 ± 25%, 800 MeV; (c) ${}^1_1$H, $\bar{\alpha}$ = 0.206 ± 20%, 81 MeV; (d) Li, $\bar{\alpha}$ = 0.0075 ± 30%, ~ 10,000 MeV; (e) ${}^1_1$H, $\bar{\alpha}$ = 0.012 ± 30%. 2000 MeV; (f) ${}^2_1$D, $\bar{\alpha}$ = 0.0053 ± 16%, 4800 MeV; (g) π-particle, $\bar{\alpha}$ = 0.029 ± 20%, 1000 MeV; *(k)* π-particle, $\bar{\alpha}$ = 0.025 ± 30%, 1200 MeV.