COSMIC RAYS

"THERE is some heretofore undreadmed-of kind of activity taking place throughout the depths of space—an activity which manifests itself in continuously raining enormously energetic bullets of some kind (photons, electrons or both) from all directions upon the heads of us mortals who live on the surface of the earth." Thus wrote Dr. Robert Andrews Millikan, famous American physicist and Nobel Laureate, a few years ago in his book *Electrons*. Dr. Millikan assisted by Dr. Neher and Dr. Pickering have been during the last fortnight investigating the nature of these bullets of energy also called cosmic rays, in Bangalore. The Government of Mysore have very kindly placed at the disposal of these scientists all facilities, and the scene of this great scientific activity has been at the *Central Observatory*.

The most outstanding feature of these rays is their very high penetrating power, far surpassing either X-rays or Gamma rays. No less characteristic is the ionisation caused by their passage through matter. The atoms or molecules in their path are torn apart and mutilated to form ions, and the extent of ionisation is measured by observing the rate of discharge of an electroscope. Dr. Neher has developed a special type of electroscope employing very delicate quartz fibres coated with gold which automatically records on a film the rate of discharge, and hence the extent of ionisation, which in its turn is a measure of the intensity of the cosmic rays at the locality. Dr. Millikan sends up a pair of balloons connected by a long tape and carrying a case containing the Neher electroscope. On reaching very high altitudes of the order of 20 to 25 kilometres one balloon bursts, and the other, unable to lift the weight of the apparatus, comes down slowly without crashing. After recovery, the film is developed to study the rate of discharge of the electroscope at the different heights attained during the flight.

Another type of apparatus employed by Drs. Millikan, Neher and Pickering depends on the use of a Geiger-Muller Counter. This is a glass tube containing a hollow metal cylinder along the axis of which is stretched a metal wire. The tube contains a suitable mixture of gases at about ten centimetres of mercury pressure. On applying a sufficiently large potential difference between the wire and the metal cylinder a discharge occurs, but if the voltage is not enough there will be no discharge. Yet the gas inside will be in a sensitive condition. A cosmic ray shooting through ionises the gas and precipitates the discharge. This event is amplified and transmitted by a tiny radio-transmitter also carried up with the counter by the balloons. These radio signals are received suitably and made to record on a uniformly moving ribbon of paper.

Investigations so far have shown that these cosmic rays consist, in large part at least, of electrically charged particles hurled into our atmosphere from outer space. Their energies are stupendous. Potentials of the order of a thousand million—even ten thousand million—volts would be needed to give these high energies. As they approach the earth, they are deflected by the earth's magnetic field which, though weak, extends to a considerable distance. The cumulative effect on the cosmic ray headed towards the earth is then considerable. In fact, particles with energies less than what they would pick up under 17,000 million volts would be unable to reach the earth at the equator in India before they were turned back into space by the earth's magnetic field. The complete story of the influence of the earth's field on these rays at different altitudes, and in different latitudes reveals to us much that is new concerning their nature.

A study of the variation of cosmic ray intensity with the magnetic latitude, especially in the equatorial belt extending up to about 40° magnetic north, yields the most valuable information. Theoretical work by Störmer, Epstein and Le Maitre and Vallarta has indicated the importance of investigations in this belt. Dr. Millikan has for this reason conducted excellent tests at Peshawar (25° magnetic north), Agra (17° magnetic north) and Bangalore (3° magnetic north).

Another equally important investigation is to study the "East-West Effect". A set of Geiger counters mounted suitably constitutes a cosmic ray telescope, and helps to measure the abundance of the cosmic rays along any direction. When it is mounted with its axis slanting at about 45° to the vertical and carried up by the balloons, the counts indicated when the telescope is eastwards and westwards can be separated by an ingenious device employing a photoelectric cell. In the west the indication are more frequent and point to the entry of a large number of positively charged particles.

Experimental evidence gained till now has testified to the uniformity of the distribution of these cosmic rays over the celestial dome. Neither the sun nor the stars seem to have any influence on their intensity. Any process which gives rise to them is regarded as not happening anywhere in our galaxy. Such atomic or nuclear transformations as might be responsible for their origin do not find the conditions obtaining on the earth, on the sun, or in the stars favourable for their occurrence. This leaves us to seek their origin down in the remote depths of space where extremely low temperature, density and pressure prevail.

To account for the origin of at least these rays which have small penetrating power—though most powerfully ionising—Dr. Millikan formerly suggested that atoms of hydrogen in these regions occasionally fuse together to build up higher elements like helium, oxygen,

silicon, iron, etc. Dr. H. N. Russell has inferred from his astronomical studies that about ninety per cent. of the universe is still in the form of hydrogen atoms. Einstein has concluded that every process which releases radiant energy must be accompanied by a corresponding decrease of mass in accordance with his relation ($E = mc^2$). Actually it is known that the mass of every higher atom is less than the sum of the masses of the several hydrogen atoms which somewhere, somehow, somewhen close up together to form the complex atom. This is known as the "packing effect" and the deficit in mass denotes the amount changed into radiation. Four hydrogen atoms, on fusing together to form a helium atom, release energy estimated to be twenty-eight million electron volts. Likewise the formations of atoms of oxygen, silicon, iron and uranium are accompanied by the release of 116, 216, 460, 1,800 million electron volts respectively. But if there is a sudden annihilation of a hydrogen atom, one thousand million electron volts are released and in the case of helium 4,000 million electron volts.

On checking up these estimates with the experimentally found values for the energies of the cosmic rays, one finds that most of them correspond to the sudden annihilation *in toto*, and the complete transformation into cosmic rays of the whole mass of some very light elements like helium, carbon, nitrogen, oxygen and silicon. The atom building process with the transformation of only a part of the mass yields too small energies to be a possible explanation of their origin. But if the whole mass of, say, the carbon atom out in interstellar space has any chance at all of transforming itself wholly into an electron pair there would thus be produced cosmic ray electrons of 6 billion electron volts energy. That sort of transformation applied to a hydrogen atom would similarly produce cosmic ray electrons of an energy of ½ billion electron volts and oxygen would thus yield 8 billion electron volts. This is precisely where the experiments of Bowen, Millikan and Neher prove conclusively that by far the greater part of the measured cosmic ray energy lies. Our knowledge of the universe so far reveals no other source of such enormous energies as are actually found in the cosmic rays; and this suggested source seems to yield approximately the correct values. This may of course be an accidental coincidence, but the India experiments are expected to throw more light on this point. Astronomers are now using the idea of the building of the heavier atoms out of hydrogen, and thus the partial transformation of mass into radiant energy to explain the age-long supply of heat energy to the sun. Dr. Millikan, who formerly used this same process to account for cosmic rays, now finds this process inadequate for the purpose. But he now finds that the complete transformation of the mass of carbon, nitrogen, oxygen and silicon atoms into cosmic radiation would be adequate. These four elements too have recently been found by Bowen to be the elements that exist most abundantly in intersteller space.

The processes of partial or complete mass transformations suggested above are such as would be in line with the assumption of the universal validity of the second law of thermodynamics. Based on this law we have the speculations of Jeans and Eddington, which carried to logical extreme imply that the universe is fated to suffer a "heat death" of final extinction of activity of all sorts. In spite of this, many scientists and philosophers wish to question the validity of this reasoning. But on this question there has never existed any experimental evidence of any sort. Yet, to deny the possibility of the transformation of radiation back into matter anywhere in the universe on the basis of our experience here on the earth represents a use of the dogma of "the heat death" of the universe. This is in no way different from the use of the worst form of ecclesiastical dogma. Dr. Millikan, the true scientist that he is, has never hesitated to express his disapproval of both kinds of dogmatism. In his opinion the dogma of the heat death of the universe would imply that we infinitesimal mites on a speck of a world know all about the universe and its workings, or more specifically that the radiation laws which appear to hold here cannot possibly have any exception anywhere else. And this is just the sort of sweeping generalisation which has lured scientists into error several times before. The situation is summed up crisply by G. N. Lewis who says that "thermodynamics gives no support to the assumption that the universe is running down. Gain in entropy always means loss of information and nothing more".

Up to the present, the study of cosmic rays has yielded no significant bearing on the question whether the universe is ultimately running down along a one-way course or whether there are processes which maintain it in equilibrium. These are questions more within the realm of the philosopher and the metaphysician and entirely outside the canvas of the experimental physicist.

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