INTERNATIONAL CONFERENCE ON COSMIC RAY PHYSICS (MOSCOW, 1959)

BY

R. R. DANIEL, M. G. K. MENON AND B. V. SREEKANTAN

Reprinted from "Current Science", October 1959, 28, 389-391

Reprinted from "Curr. Sci.", October 1959, 28, 389-391

INTERNATIONAL CONFERENCE ON COSMIC RAY PHYSICS (MOSCOW, 1959)

THE biennial Cosmic Ray Conference organised by the International Union of Pure and Applied Physics was held in Moscow from 6th to 11th July, 1959 ; this was the first time that this Conference was held in the U.S.S.R. About 250 scientists from 25 countries including India participated ; out of this about 175 were from the U.S.S.R. A total of about 175 original papers were presented under the following heads :

(*i*) Nuclear interactions at high energies. (*ii*) Extensive air showers. (*iii*) Experiments on the primary radiation using balloons, rockets and satellites. (*iv*) Cosmic ray intensity variations. (*v*) Origin of cosmic rays and related astrophysical aspects.

Plenary sessions were held in the mornings, at which the more important papers and papers covering the overall work of large groups were presented. In the afternoons two parallel sessions were usually held, where results of a more detailed nature were reported and discussed.

(i) Nuclear Interactions at High Energies :

It is clear that, for a very long time to come, nuclear interactions above 100 BeV will be studied by cosmic ray experiments alone. In order to investigate these, the so-called jets, with photographic emulsions, it is necessary to expose large stacks at high altitude for long periods of time ; this is because the very high energy particles are extremely rare in the cosmic radiation. The cost of such a stack is enormous ; for example, a stack one metre square and one mean free path deep costs about 15 lakhs of rupees. A further difficulty is the location of these jets. These difficulties are removed to a large extent through the use of "emulsion chambers" which are made up of layers of emulsion interleaved with thin plates of elements of high atomic weight, such as lead and tungsten. Such an assembly is not only very much cheaper than a similar stack of emulsion but also allows easy location of the jets by visual examination of the emulsions close to the lead or tungsten plates for high density electro-magnetic cascades. Such assemblies have been used on a small scale in the past ; but recently the Japanese Co-operative emulsion group (Fujimoto, Nishimura and others) and the Bristol emulsion group (Fowler, Perkins and others) have used them on a large scale. The Bristol group have exposed an assembly of 1 cu. ft. in volume for 1,200 hours on high flying Comet aircraft. From a study of electro-magnetic cascades they find that the integral energy spectrum, $N(>E) \propto 1/E_n$, for γ-ray energies between 10^{12}-10^{13} ev. has an exponent $n = 3 \cdot 5$; a similar exponent is found for γ-rays of similar energy arising from the decay of π^0-mesons produced in nuclear interactions in the emulsion. The value of n for the primary radiation is known to be about $1 \cdot 7$. This observation, if confirmed, could mean that there is either a sharp cut-off of the primary energy spectrum at an energy of about 10^{15} ev./nucleon, or that the energy going into pions at these high energies is greatly reduced ; this latter conclusion, taken with other evidence, would indicate appreciable production of particles other than pions at these energies. The Japanese group, using a similar arrangement at mountain altitude, obtain for γ-rays of energy between 10^{11} and 10^{12} ev. an exponent of $2 \cdot 0$. There is thus an indication at this stage that there is something new occurring in the range of primary energies which contribute to the production of photons of energy between 10^{12} and 10^{13} ev. Experiments using such chambers will be carried out extensively in the near future at mountain, airplane and balloon altitudes ; the very heavy weight of these assemblies, about a ton, and the long exposures, of the order of days, put a considerable strain on balloon techniques.

A serious difficulty in these investigations is that there is no way, at the moment, of estimating the energy of the primary particles. A conventional method has been to derive the primary energy from the angular distribution of secondary relativistic particles ; the basic assumptions underlying these have been questioned. A Russian group (Grigorov and others) have set up an "Ionisation Calorimeter" consisting of alternate layers of lead (or iron) and some particle detector such as ionisation chambers and photographic emulsions. The primary particle interacts in a layer of graphite above this assembly and the secondary particles travel through the calorimeter, in which they produce further interactions, and the various particles lose energy in ionisation process. The total depth of the ionisation calorimeter is sufficient to ensure that all the energy brought by the primary particle and distributed to the secondary particles is expended in it in the form of ionisation; this represents a direct estimation of the primary energy, and the accuracy obtainable is $\sim 30\%$. Preliminary results obtained with this arrangement were reported.

A review talk was given by Feinberg on the present status of our theoretical understanding of phenomena at these energies. A number of interesting papers were also reported on the analysis of high energy interactions, particularly on the existence of asymmetries in the angular distribution of secondary particles in the centre of mass system and its bearing on the question of the number of centres in the C.M. system from which the secondary particles are emitted.

(ii) Extensive Air Showers:

Results on extensive air showers (EAS) were presented by the large groups working at Moscow, M.I.T., Cornell and Tokyo. The role played by fluctuations in the interpretation of EAS was one of the main topics of discussion at the Conference. Basically, there are three types of fluctuations: (*a*) the primary particle may be a proton or a heavier nucleus with charge from 2 up to 26; (*b*) the level of the first collision will show considerable fluctuation with respect to the top of the atmosphere and (*c*) the characteristics of the various collisions in the atmosphere—the number of pions produced, their angular distribution, the inelasticities involved, etc.—and their energy dependence can cause considerable fluctuations. The Japanese group was strongly of the view that cause (*b*) was the main source of fluctuations. Experimental results on the fluctuations of core structure, energy flow, lateral distribution of particles and on the longitudinal development of the shower (by observations on the Cerenkov radiation produced in the atmosphere at different altitudes) were presented by the Russian group and the results on the fluctuations in the muon component of EAS by the Japanese group. The M.I.T. and the Cornell groups reported evidence for the existence of showers containing as many as 10^9 to 10^{10} particles, as also the more recent data for the number spectrum, absorption mean free path, etc. One of the more interesting observations is that of multiple penetrating showers observed in cloud chambers at mountain altitudes, as also that of a number of bunches of parallel penetrating particles deep underground; the mechanism responsible for the production of these is not yet clear.

(iii) Experiments on the Primary Radiation Using Balloons, Rockets and Satellites:

The most spectacular reports in this session relate to the existence of intense radiation zones surrounding the earth, the inner one extending from about 1,000 km. to 8,000 km. and the outer one from about 15,000 km. to 50,000 km. The properties of these zones, as derived from the limited number of observations made so far, are as follows:

(*a*) *The Inner Zone.*—The particles in the inner zone are electrons and protons. The existence of protons in the zone is established by emulsion observations. The electrons are mainly of low energy; experiments with a magnetic spectrometer show that, between 30 KeV. and 4 MeV., 99% have energies less than 600 KeV. The integral range spectrum of the radiation falls by two orders of magnitude from 1 mg./cm.^{2} to about 140 mg./cm.^{2}—these are mainly electrons—then trails out more gradually towards greater stopping power. Of the radiation which penetrates 140 mg./cm.^{2} a fraction of 1% penetrates several grams per square centimetre. The inner zone is relatively stable as a function of time. Protons and electrons arising from the decay of albedo neutrons and trapped in the earth's magnetic field could be an important input to the inner zone. That this can be so was demonstrated by the Argus experiment in which small yield atomic devices were exploded at high altitudes and the β-decay electrons from the fission fragments observed in the inner zone. Whether the albedo particles can explain the features of the inner zone quantitatively is not yet known.

(*b*) *The Outer Zone.*—It is now fairly well established that the overwhelming majority ($> 98\%$) of particles in the outer zone are electrons. The energy spectrum apparently resembles that of the auroral soft radiation —rising sharply towards low energies from a practical upper limit of about 100 KeV. Further, the spectrum in the central region is softer than at the fringes, the effective energies being 25 KeV. in the central region and 50 KeV. at the fringes. Measurements with Pioneer IV (of 3 March, 1959) showed that the maximum intensity was much greater at that time than that observed with Pioneer III (of 7 December, 1958) and extended some 15,000 km. further out. This large temporal fluctuation provides the most important evidence for the solar origin of, at least, the outer zone; just prior to the Pioneer IV observations, there was a great M-region event on the sun (on February 25, 1959).

The interplanetary cosmic ray intensity has been estimated to be $0 \cdot 18 \pm 0 \cdot 008$ charged particles/cm.^{2} sec. sterad. The photon intensity in the energy interval 45-450 KeV. is $3 \cdot 0 \pm 0 \cdot 1$

photons/cm.^{2} sec. sterad ; this is still subject to doubt.

(iv) Cosmic Ray Intensity Variations :

New information regarding cosmic ray intensity variations comes from the large amount of work done at various laboratories in connection with the I.G.Y. The most striking observation that has been made in this field is the high degree of correlation that is found to exist between the cosmic ray intensity variations and solar flares, solar radio emission, radio fade outs and ionospheric disturbances, magnetic storms and auroral displays. This correlation has been established by the simultaneous observations on different geophysical phenomena during the I.G.Y. and since then. The time correlations observed are mostly interpreted in terms of solar corpuscular streams carrying frozen magnetic fields. The passage of the earth through these streams of ionized plasma and the consequent effects on the geomagnetic field at points away from the earth's surface is considered to be responsible for many of the observed effects.

An interesting observation by the Minnesota group might be mentioned here. They made a series of balloon ascents carrying photographic emulsions on receipt of information concerning enhanced solar activity (solar flare 3 + on 10th May, 1959). On the initial ascents the emulsions showed a normal background of tracks and then in a flight a few hours later the emulsions recorded an enormous intensity of low energy (50-500 MeV.) proton tracks. The visual difference between this and the emulsion exposed a few hours before was spectacular. The presence of the low energy particles was interpreted in terms of the distortion of the Stormer cut-offs by the solar stream—the arrival of which also produced strong auroræ, solar noise and a magnetic storm.

(v) Theories of the Origin of Cosmic Radiation and Related Astrophysical Phenomena :

No new theories on the origin of cosmic radiation were presented. An interesting review of this subject, particularly on the theory of the supernovæ origin of cosmic radiation, was presented by Ginsburg. As a result of radio-astronomical observations carried out during the last two years a number of the parameters needed to elaborate this theory are much better measured and understood. This appears to be the only real theory at the moment which has a quantitative basis.

The next Conference of this type will be held in Japan in 1961.

Tata Institute of Fundamental Research, Bombay-1.

R. R. Daniel.
M. G. K. Menon.
B. V. Sreekantan.