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ON THE ULTRA-SOFT COMPONENT OF THE COSMIC RADIATION

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ON THE ULTRA SOFT COMPONENT OF THE COSMIC RADIATION

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Discutem-se os resultados de experiências feitas em São Paulo, a uma altitude de 800 metros acima do nivel do mar, com tubos contadores de construção especial, visando obter dados sobre a componente "ultra-mole" da radiação cósmica.

Das medidas realizadas e da sua interpretação tiram-se conclusões sôbre o poder de penetração dos compúsculos que constituem essa componente e sôbre a porcentagem da componente mole na radiação cósmica total.

Most investigation on cosmic rays dealt with the penetrating particles. From this circumstance it resulted that much was known about the high energy part of the spectrum and little about the small energy one. Recently the study of the soft radiation became of interest, since the soft particles play an important part in the phenomena of nuclear evaporation, explosion showers and in the determination of the mass of the cosmic ray particles.

This communication is concerned with a rough examination of the non penetrating particles in the cosmic radiation. Without any prejudgement on their nature and the energy associated with this part of the spectrum, we shall call it the ultra soft component (U. S. C.).

In 1939 one of us (M. S.) (1) has brought out that if we compare the results, of Pfotzer and those of Bowen, Millikan and Neher (fig. 1), the measurements with ionization chambers are higher than those with counters. He suggested that this fact was due to the existence at high altitude of a strong percentage in the radiation of short range particles and of groups of particles which the ionization chamber recorded selectively.

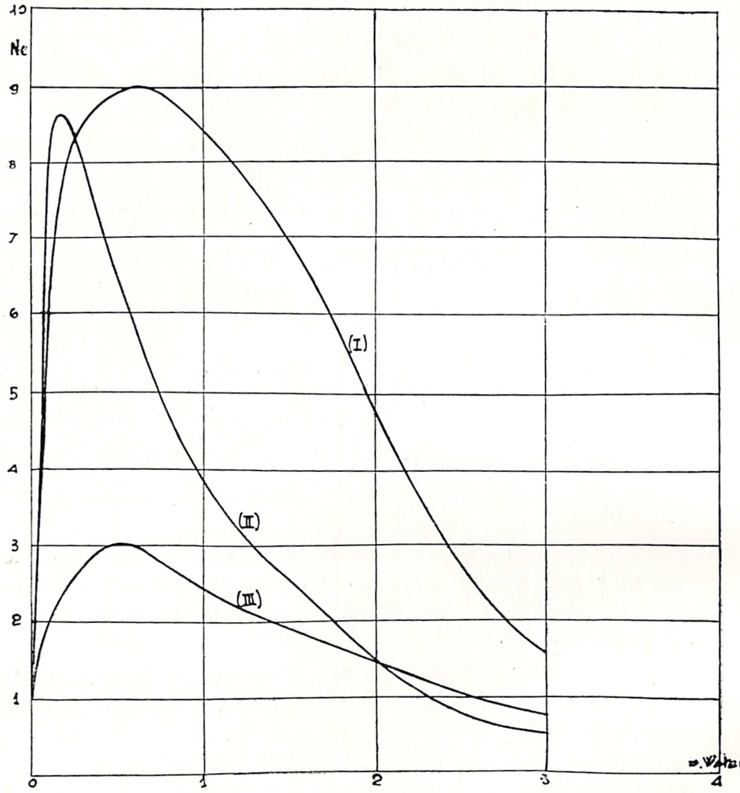


Fig. 1

I — Bowen — Millikan and Neher differential curve for 11×10^3MEV.
II — Bowen — Millikan and Neher differential curve for 1.5×10^3MEV.
III — Pfötzer's curve transformed for all directions incidence.

We present here the results obtained by us in investigations perfomed in order to know whether any effect of this type is present at the altitude of 800 m., in São Paulo. The feature of our telescope counter were :

1) The two counters worked outside the building, practically at open air, under a silk tent of 0,3 mm. thikness.

2) We used two counters of aluminum thickness 0.15 mm. as a vertical telescope ; they had a diameter of 1.2 cm. and an effective length of 6 cm.

3) The choice of two counters as well as their reduced dimensions has not been casual. It might seem that the best arrangement would have been *three counters* of large dimensions, in order to bring up the measured intensity and to bring down the percentage of casual coincidences. However, for low energy particles, wall scattering and absorption become important. These facts forbid the use of three counters for the detection of particles of small range.

Besides, is is very difficult to have aluminum counters working with 100% efficiency. Low efficiency means selection : to increase the number of the counters means selection of the counted particles, the tendency being to overestimate the number of highly ionizing particles, in comparison with those of low ionization, or of groups preferably to isolated particles. Large area means higher sensitivity to groups of particles.

As we are going to see, the results of our experiments have confirmed the necessity of working with two counters of small dimensions.

During the whole experiment hereby reported, a close watch was kept on the barometer's readings. The athmospheric conditions being very stable in São Paulo during the winter, in which period our investigations were performed, we did not need to apply any correction.

I) First we measured the absorption of the radiation with a vertical telescope. The results are seen in fig. 2, in which the ordinates represent the number of coincidences per minute ; the abscissae represent the absorbing thicknesses between the counters.

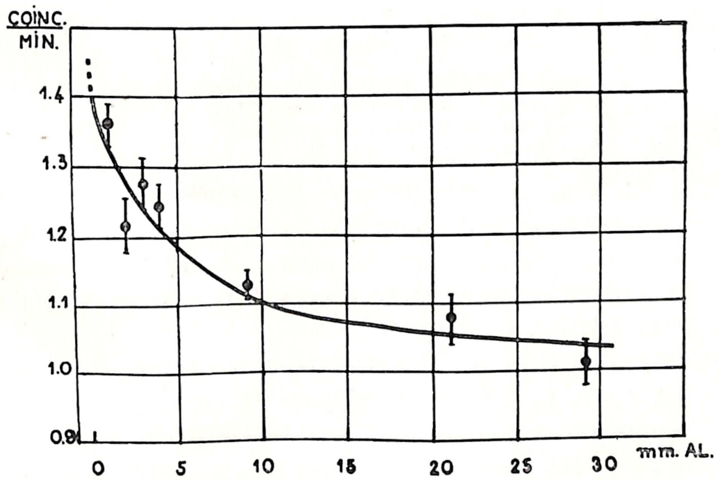


Fig. 2

Absorption curve of the particles coming from the air. (S. Paulo)

The zero abscissa corresponds to the total thickness of the three counter walls (0,45 mm. Al). A part of the coincidences for the smallest thicknesses, must clearly be due to particles of terrestrial origin, but not all of them. The existence of hard cosmic particles implies the presence of soft cosmic ones. If we consider as being of cosmic origin only the particles in the spectrum with a range over 4 mm.Al. (more than 2.10^{6} e. v.), in the hypothesis of their being electrons, the percentage of U. S. C. no total radiation is 12 %. But this limit is too severe. If we draw an extrapolation at 0 absorber, assuming for the total radiation an intensity of 1.4 impulses per minute, we get 30% for the ratio between U. S. C. and total radiation. The real value must lie between these two limits. We shall assume it to be 20%.

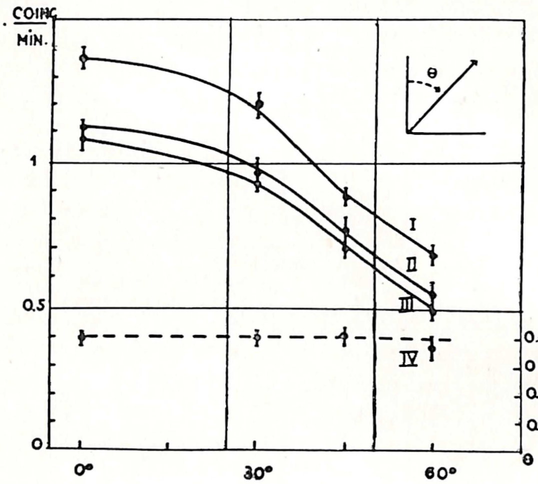


Fig. 3

I — No absorber between the counters
II — 2 mm Pb between the counters
III — 5 mm Pb between the counters
IV — Ratio between I and III

II) The variation of intensity with the inclination of the telescope is shown in fig. 3. It shows that inside the limits of our statistical errors, the percentage remains the same in any direction. It shows also that under any inclination the number of particles between 0 and 5.10^6 e. v. is greater than between 5.10^6 and 10^7 e. v.

Though this result is in line with that found in (I), the conclusion must be carefully tested, for it would afford evidence of radioactive gases in the air around.

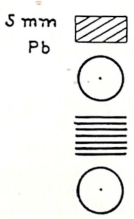
The complex of the evidence given by the absorption measurements and by the azimuthal effect seems to show a spectral distribution of the U. S. C. intensity which maximum lies in the region from 0 to 6.10^6 e. v.

TABLE I

DIFFUSOR	N	Min.	N/Min.
Pb 0 mm	779	590	1·32 ±0·047
2	854	591	1·44 ±0·049
5	1048	632	1·66 ±0·051
7	687	418	1·642 ±0·063
Ag 5 mm	209	129	1·62 ±0·112

III) The evidence that a part of the U. S. C. is associated with secondary rays is contained in Table I and the absorption of particles coming from 5 mm. Pb. is shown in Table II and fig. 4.

TABLE II



ABSORBER	N	Min	N/Min
Pb 0 mm	1048	632	1.658±0.051
3	177	135	1.311±0.098
5	690	563	1.225±0.046
7	1034	897	1.153±0.036
Ag 5 mm	884	734	1.204±0.041

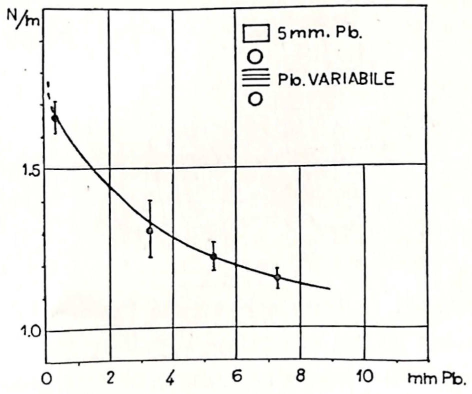


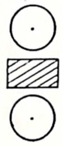
Fig. 4

Absorption curve of the radiation coming from 5 mm Pb.

This experiment suggests that a part at least of the coincidences we register are due to materialisation of uncharged rays and that the energy of the secondary particles is of the same order as the U. S. C. of the air, as shown in fig. 1.

These measurements show that we are in a region in which the absorption must be correlated with the atomic number. We have tried to show this difference between the particles, absorbing them in equal layers of lead and silver. As these two elements have equal electronic densities, the results are geometrically comparable. We have performed this experiment with different absorber thicknesses, from 2 to 7 mm. In Table III is shown a particularly accurate run, but all the others gave the same result, inside the limits of larger statistical errors.

TABLE III



ABSORBER	N	Min	N/Min
Pb 7 mm	790	726	1.09±0.039
Ag 7 mm	1378	1289	1.07±0.029

These results can be interpreted as meaning that :

a) If the particles are electrons, there are very few particles in the region in which the difference is looked for.

b) A strong association between the detected particles covers the difference, following the rough scheme of fig. 5.

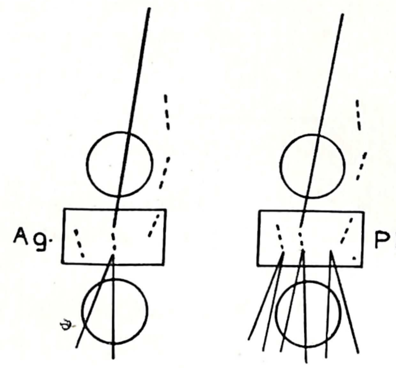


Fig. 5

IV) We have tried to put in evidence this association effect with the same two counters used in the preceding research, but horizontally disposed. We inserted an aluminium plate of 4 mm. thickness between the counters, in order to absorb the horizontal radiation. In this way the zero effect was reduced to some 80 % of the initial effect.

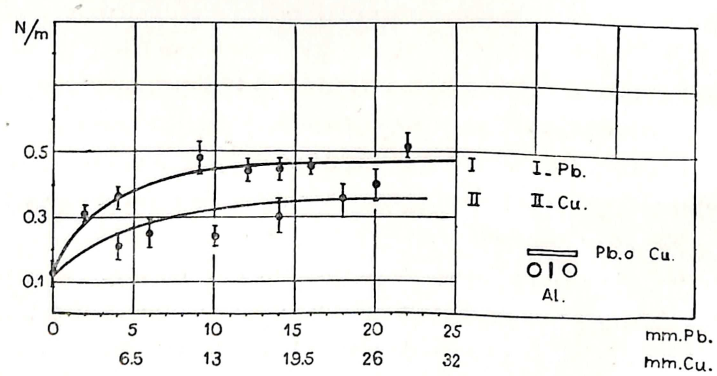


Fig. 6

We have used lead and copper as scatterers. The results are shown in fig. 6. The curves are not Rossi curves, but they are similar in shape to those that Starr (3) deduced from Wilson's chamber measurements for showers of few particles.

The absorption of groups coming out from 1.6 cm. Pb. has been tried in Aluminum. The accuracy of the measurement is not very high, but it is good enough to show that the penetration of the secondary particles is low (5 mm. Pb.).

It might seem interesting, in order to decide which part of the spectrum the U. S. C. is associated with, to compare our results with those of other authors, obtained in different geographical places. We believe however that little meaning can be attributed to any comparison.

a) Williams (4), using a random operated Wilson chamber, finds that 8% of the cosmic radiation lies in the region between 3.10^6 and 10^7 e. v. Considering that our experiments were done at 800 m. and that our extrapolation at 3.10^6 gave 12%, the concordance seems quite good. Given the influence of the secondary effects we consider this as only fortuitous.

The evidence we have shown indicates that we deal with a mixture of beta and gamma rays, and that surrounding material will affect the measured intensity in a quite impredictable way.

The beta rays come in the air from a distance of 5 to 20 meters, and in a solenoid field they will be prevented by it to enter the chamber, even if we do not take into account the absorption in the chamber's walls. The low energy particles measured by other authors are the hard ones, slowed, and the secondaries of the gamma rays.

On the other hand, in this energy range any absorbing layer produces a change in the quality of the incoming radiation. Williams worked inside a building with a Wilson chamber of heavy material and magnetic coils around. It can only be said that he has measured the amount of soft local radiation inside the chamber, but for our purpose this result has little interest.

Regarding intensity measurements, the results of an ordinary Wilson chamber are subject to caution. The chamber must indicate a ratio of hard particles to soft ones higher than the actual ones. The chamber is in most cases bidimensional. In associated phenomena that generally come in vertically or at any angle, only particles which cross the chamber are detected.

In showers the angular spread is larger for small energy particles than for the energetic ones. So, when a many-particles phenomenon is studied and we count particles coming in groups, we should not forget that there is a better chance to record the particles having most energy.

b) The effect of association produced by the surrounding material makes still more difficult to compare our results with others obtained with counter telescope by other authors. We shall refer briefly to the work of Bernardini and Ferretti (1938-1939) (5) and of Clay and Jonker (1938) (6).

The experiments of Bernardini and Ferretti were performed with an adequate technique : 3-fold coincidences, thin walled counters, telescope axis inclined at 45°. They find for the U. S. C. from the air 25%. This effect is somehow greater than ours, exactly as the association effect ought to give due to the bigger solid angle of their telescope and to the secondaries coming from the glass of the room.

For gamma rays the effect is smaller : they find a $5\% \pm 3\%$ increase with 4 mm. of Pb. over the counters. Although the size of our counters was smaller, the distance between the two elements of our telescope was smaller than the distance between the 1st and 3rd axis of theirs : the solid angle to the lead scatterer was much bigger. They too found independently from us equal absorption with elements having the same atomic number and they attributed it to Compton-effect interaction, which, as we have shown in experiments III and Fig. 4 is only partially true.

A definite comparison with the results of Clay and Jonker is very difficult. The apparatus was too different : their counters were practically inbedded in lead, in order to protect them from stray radiations. Their walls were very thick and long : 1 mm. steel thickness, 27 cm lenght.

They found a gamma ray effect, but we are unable to compare their numerical increasse for gamma rays with ours : the corrections to be done were too many, and too uncertain.

The evidence shown in this paper seems to encourage several conclusions.

1) The mean penetration of these particles is very low. This shows that in coincidence measurements the fraction lost by absorption in the walls of the counters and by scattering will be high, and in a minor degree when material around will modify the beam constitution the same shall happen with a single counter. This shows that even the Rossi curves do not give an accurate experimental picture of the phenomenon. This affords ground to the supposition of Arley and Blackett concerning the results of Clay and Maas.

2) In what regards the evaluation of the electronic part of the radiation, the existence of at least 15% soft radiation, which is not usually detected, must be taken into account, so the value of 30% for the ratio between soft component and total radiation, at 1,000 m. obtained with counters, can be safely increased up to a value between 40 and 50% for counters measurements.

3) Close association between hard and soft component has been recently used by various investigators : (Schönberg, Arley, Clay, Blackett, Nordheim), to pull together experiment and theory about showers and mesons. It may

seem that the authors of this paper have always taken the view that the close association they found occur only between soft radiation and gamma rays. We have only explained our results in terms of well known facts, since there was no cogent evidence of a new phenomenon. As a matter of fact, the results of table II and table III can be explained by either one of the schemes of fig. 7, if not by all of them together. It is clear that only a specially designed experiment could settle this question. The authors think that both phenomena contribute to the effect they have found.

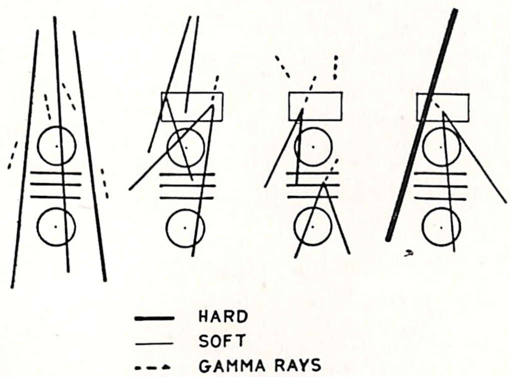


Fig. 7

Quite recently different laboratories have reported evidence of groups of associated penetrating particles that discharge counters under deep layers of lead. The largest part of these phenomena must certainly be attributed to penetrating particles. It still remains to be seen if a fraction of the observed intensity is not due to flashes of gamma rays accompanying those particles. The effect is not to be compared of course to the action of a gamma ray source concentrated in a point. The gamma ray emission is bound in time and space with the penetrating particles. The energy of the most energetic gamma rays will degrade very fast, but is must be taken into account that they will reach the maximum penetration when the energy is of the order of 3.10^{6} e. v. And this is the energy we find for the bulk of the U. S. C.

If the measurements here discussed are correct, it is clear that this part of the spectrum must play an important part in any conclusion that we can draw from the general picture of the cosmic ray phenomena.

These experiments were performed in the period from May to October 1939, at The Department of Physics of the University of S. Paulo.

Rio de Janeiro, August 5, 1941.

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