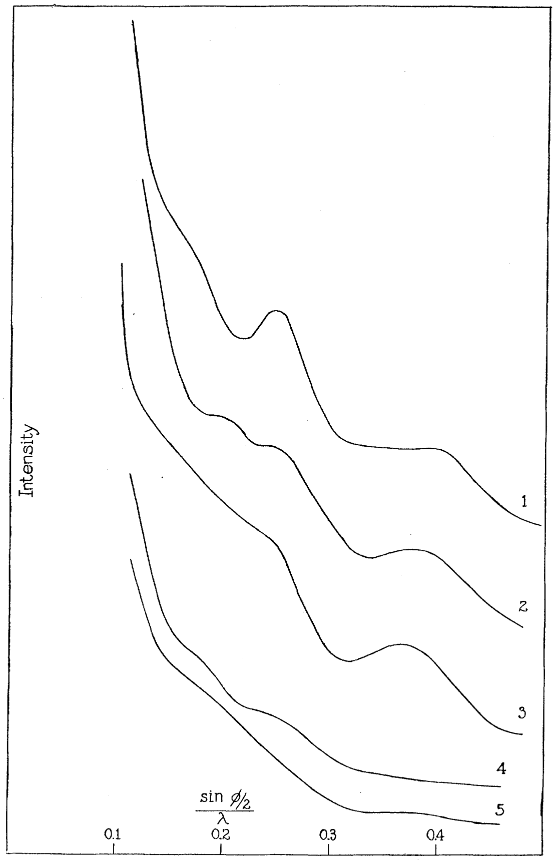

FIG. 1

of the angular positions of the peaks. The theoretical scattering curves differ markedly from the scattering curves for the Cl atoms alone because of the influence of the C–C scattering and the C–Cl. For example the main peak in curve 1 is at about the position of the third order peak in the simple Cl–Cl curve.

A comparison of the experimental and theoretical curves shows good agreement in peak positions. The large angle peak in ortho is entirely missing from the para, while ortho shows no pronounced peak at small angles. The differences are even more pronounced in visual comparison of the films. A film for meta also shows good agreement. It has no pronounced small angle peak but a heavy blackening at slightly larger angles than the ortho and has a very faint large angle peak at a slightly larger angle than that for the ortho. While this agreement between experiment and theory based on a model does not prove that the model postulated is a unique solution it does offer additional evidence in favor of the plane ring with substituents in the same plane and stronger evidence that atoms in the para position are about twice the distance apart of those in the ortho position. The meta distance seems to be intermediate between the ortho and para. More definite evidence may be obtained from a quantitative comparison of the theoretical and experimental curves after the latter have been corrected for polarization, incoherent scattering and variable blackening on the film.

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The Effect of Secondary Emission from a Metal Collector Immersed in a Discharge

Recently there have appeared several papers treating the secondary emission from collectors immersed in a discharge.[1] However, no experiments have been carried out in which this effect would be shown directly.

To study the effect of secondary emission from a collector a hot-cathode discharge tube, 5 cm in diameter, containing saturated mercury vapor, was constructed. The tube contained a cylinder and two disk-shaped plane collectors, 0.9 cm in diameter. The plane of one of the disk-shaped collectors coincided with the cross-section plane of the tube (in the following it will be mentioned as collector No. 1), while the plane of the other collector was parallel to the axis of the tube (collector No. 2 in the following). Semi-logarithmic volt-ampere characteristics of both collectors were found to be sharply different in the region of high negative voltage with respect to the anode, while the linear parts of these characteristics, which correspond to ultimate (low-speed) electrons, practically coincided. The part corresponding to the region of saturation (after the kink in the characteristics) were always higher for collector No. 2, than for collector No. 1, though at high negative voltage the current flowing to collector No. 1 was always higher than to collector No. 2. Moreover, the transition to saturation was considerably sharper for collector No. 2, than for No. 1. Only at high positive voltages did the current flowing to collector No. 1 become equal to that flowing to collector No. 2. An analysis of the characteristics made according to Langmuir and Mott-Smith theory, showed that the difference in the characteristics in the region of high negative voltages was due to a current of primary (high-speed) electrons, which reach collector No. 1, but do not reach collector No. 2. This causes the difference in the characteristics in the saturation region as the high-speed primary electrons reaching collector No. 1 produce a high secondary emission from this collector. Therefore the current flowing to collector No. 1 in the saturation region will always be less than that flowing to collector No. 2. Thus we have a direct proof that secondary emission plays an important rôle in the transition parts of the characteristics. With a cylindrical collector no sharp transition necessary for an accurate determination of the reflection factor was ever observed in the saturation region.

[1] Lamar and K. T. Compton, Phys. Rev. **37**, 1069 (1931); Kommnic, Ann. d. Physik. **15**, 3 (1932).

From the characteristics of collector No. 2 which are not affected by the distorting action of high-speed primary electrons the reflection factors for ultimate electrons can be obtained. Thus, for example with a nickel collector, for a temperature of electron distribution $T_e = 15{,}000°K$, the reflection factor α for ultimate electrons was found to be 0.28.

It is interesting to note, that the positive ion sheath of collector No. 1 was always thinner on the cathode side, than on the anode side.[2] Under certain conditions we could observe the typical electron sheath breakdown curves[3] for collector No. 1.

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Physical Research Institute,
Moscow-University,
January 9, 1933.

[2] Compare L. Tonks and I. Langmuir, Phys. Rev. **34**, 899 (1929).

[3] I. Langmuir, J. Franklin Institute **214**, 275 (1932).

How Far Do Cosmic Rays Travel?

Two entirely different suggestions have been advanced in the literature as to *where* the cosmic rays originate. The first suggestion is that cosmic rays are of local origin (upper earth atmosphere, our own planetary system, etc.). The other suggestion is that cosmic rays are produced or have been produced throughout the universe, or even more specifically, throughout interstellar or intergalactic spaces. This latter view has especially been advanced by R. A. Millikan.

The purpose of this paper is to examine these hypotheses somewhat more closely and to establish a relation between them and the red shift of extragalactic-nebulae.

Suppose that on the basis of the second suggestion mentioned above, the generation of cosmic rays is given as ϵ erg/cm³ sec., where $\epsilon = \epsilon(r)$ is only a function of the distance r from the observer. Then the radiation intensity σ from a half sphere of radius R is given by

$$\sigma = \frac{1}{4}\int_0^R \epsilon(r)dr \text{ in ergs/cm}^2 \text{ sec.} \tag{1}$$

Provided that $\epsilon(r) = \epsilon_0 =$ constant, this gives

$$\sigma = \epsilon_0 R/4. \tag{2}$$

We know, however, that, because of the red shift

$$\epsilon(r) = \epsilon_0(1 - r/D) \tag{3}$$

where $D \sim 2000 \times 10^6$ light years. This gives

$$\sigma = (\epsilon_0 R/4)(1 - R/2D) \tag{4}$$

or if the red shift is proportional to r all the way up to $r = D$ the total intensity from the universe

$$\sigma_t = \epsilon_0 D/8. \tag{5}$$

In these cases no light signal could ever reach us from distances $r > D$. In spite of an infinite number of luminous stars, σ_t would be finite and one of the old arguments for the necessity of a finite space would have to be discarded.

The difficulty which arises in relation to the suggestion that cosmic rays are created throughout intergalactic space now is this. According to the observational data the ratios of the intensity due to the galaxy σ_g and the intensity due to the rest of the universe σ_u are

$$a = \sigma_g/\sigma_u \gg 1 \text{ for visible light} \tag{6}$$

$$b = \sigma_g/\sigma_u \ll 1 \text{ for the cosmic rays.} \tag{7}$$

The ratio a/b is equal at the very least to a hundred. It is therefore impossible that the cosmic rays, if photons, come from luminous matter. Now according to the present estimates the average density of dark matter in our galaxy (ρ_g) and throughout the rest of the universe (ρ_u) are in the ratio

$$\rho_g/\rho_u > 100{,}000. \tag{8}$$

If we assume that the cosmic rays are produced at a rate proportional to the density, then it follows that the above ratio b for the cosmic rays according to (2) can only be explained if these rays are collected from all distances up to $10^7 \times d$ light years where $d > 10{,}000$ light years is the radius of our galaxy. This would correspond to a distance greater than 10^{11} light years. Now if the red shift were linear with distance all the time, no cosmic-ray photon could reach us from distances greater than 2×10^9 light years. The discrepancy becomes still worse, as Dr. Tolman kindly informs me, if the cosmic rays consist of any particles of matter such as electrons or neutrons.

The following suggestions might be advanced in order to remove the above discrepancy.

(1) The extragalactic red shift may increase less than proportional to the distance for very great distances. The corresponding Doppler velocity at great distances however must then relatively soon approach quite closely the velocity of light in order to prevent a too great amount of visible light reaching us from distant hot stars (O, B-stars, etc.). It is also to be remembered that the simple Einstein-de Sitter theory requires the red shift to increase faster than the distance.

(2) The ratio (8) may be much smaller than assumed above. Difficulties however may arise contradicting the so far observed emptiness of extragalactic space. It is also to be remembered that cosmic rays at any rate are probably more strongly absorbed by any kind of interstellar matter than visible light.

(3) The "chemical reaction" producing the cosmic rays may be of a negative order, that is, it might be *proportional to some inverse power of the density.* One might picture, for instance, a set of quantum states of space which according to the exclusion principle is entirely filled up at higher densities. Free states might exist at very low densities and facilitate processes which are not possible at higher pressures.

(4) Cosmic rays may have been produced at a time when the universe was in an entirely different state than it is