on which the foregoing results are based were obtained on March 28, 1948, between $22^h\ 05^m$ and $22^h\ 53^m$ U.T., with the sun at an average altitude of 14°34′.

The calculated temperature of −37°C is a reasonable value, being that normally found at a height of about 8 km.[2] Pending further study, nothing definite can be stated as to the lateral and vertical distribution of the methane in the earth's atmosphere. The indicated average height of 8 km is reasonable for the relatively light CH_4 molecule. Analysis of tracings made with the sun at various altitudes should provide further information on the vertical distribution.

[1] Marcel V. Migeotte, Phys. Rev. 73, 519 (1948); McMath, Mohler, and Goldberg, *ibid.* 1203 (1948).
[2] *Smithsonian Physical Tables* (1934), p. 559.

Plasma Oscillations as a Cause of Acceleration of Cosmic-Ray Particles

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July 12, 1948

ONE of the earliest hypotheses to explain the high energies of cosmic rays postulated weak interstellar electric fields, extending over enormous distances in space. These fields cannot be static because the known concentration of highly mobile ions in space rapidly produces neutralization. On the other hand, if an appreciable number of high energy particles are to be obtained from small oscillatory or fluctuating fields, it seems essential that there be present systematic effects producing cumulative energy transfers of the same sign over a long period of time. We wish to suggest here that plasma oscillations of ion clouds in intra-galactic space can provide such a mechanism of cumulative energy transfers.

About 15 percent of the volume of intra-galactic space is occupied by dust clouds, in which the ion density is of the order of 1 per cm^3. Like any other ion gas, this system constitutes a plasma[1] which can execute longitudinal electronic oscillations of angular frequency,[2]

$$\omega^2=(4\pi n_0\epsilon^2/m)+(3kT/m)(2\pi/\lambda)^2,$$

where n_0 is the mean electron density, T the electron temperature, and λ the wave-length. The electron temperature in these gases usually corresponds to a mean kinetic energy of a few ev.

It is found, experimentally[1] and theoretically,[3] that plasma oscillations are readily excited by special groups of electrons which have appreciably more than the mean thermal kinetic energy. To excite the interstellar plasma, one requires electrons of about 5 ev, or more, which can be provided by photo-ionization, and perhaps also by emission of streams of charge from hot stars.

Under the influence of a plasma oscillation of small amplitude, most particles will merely experience correspondingly small oscillatory changes of velocity. A particle which happens to be moving with a velocity close to the phase velocity of the wave, however, can be trapped in the trough of the potential, so that it oscillates about a mean speed equal to that of the wave. If the phase velocity should for any reason increase very gradually in the direction of propagation, this particle would tend to remain trapped, and thus would oscillate about an ever-increasing wave velocity. Inspection of the formula for the plasma frequency shows that such an increase of phase velocity is obtained whenever a wave enters a region of increasing ion density. In fact, as n_0 approaches $(m\omega^2/4\pi\epsilon^2)$, the phase velocity grows without limit, thus providing, in principle at least, a mechanism for accelerating particles to arbitrarily high energies. At some point near the above critical density, however, the particle ceases to be trapped, because its mass eventually becomes so great that the electric fields in the wave can no longer supply the mean acceleration needed to match the increase in phase velocity. The maximum energy attainable is determined by the wave amplitude, and this depends on the balance of excitation and damping processes which we hope to investigate in detail.

An important question is whether enough energy can be fed into plasma oscillations to maintain the known flux of cosmic-ray energy. The mean energy density in cosmic rays[4] is about one-fifth that of starlight[5] in interstellar space. If there is a small galactic magnetic field,[6,7] however, as has been suggested on other grounds, each cosmic-ray particle could move in a large orbit making as many as 10,000 revolutions before being absorbed, so that, to maintain the observed flux of cosmic rays, it would be necessary to supply only about 2×10^{-5} of the energy in starlight. It is fairly likely[8] that as much as 10^{-3} of the total energy in starlight goes into photo-ionization; hence this source alone may be adequate.

The final energy spectrum would depend, first, on the details of the acceleration process, and second, on the subsequent degradation in interstellar space.

[1] I. Langmuir, Proc. Nat. Sci. 14, 627 (1928).
[2] J. J. Thomson, *Conduction of Electricity in Gases* (Cambridge University Press, Teddington), p. 353.
[3] D. Bohm and E. P. Gross, Phys. Rev. (to be published).
[4] L. Janossy, *Cosmic Rays* (Oxford University Press, London, 1947), p. 298.
[5] T. Dunham, Proc. Am. Phil. Soc. 81, 277 (1939).
[6] H. Alfven, Zeits. f. Physik 107, 579 (1937).
[7] L. Spitzer, Phys. Rev. 70, 777 (1946).
[8] L. Spitzer (private communication).

An Investigation of Samarium and Gadolinium by the Photographic Method*

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July 12, 1948

MÄDER[1] and Taylor[2] reported that long-range particles were emitted by Sm and suspected that these were protons. However, Cuer and Lattes[3] showed that these were not unique to Sm but appeared also from Nd in each instance with a track length corresponding to Po α-particles. They therefore suggested Po contamination as a source of long-range alphas.

A portion of an Ilford C2 Plate was impregnated with $Sm(NO_3)_3$ prepared from pure Sm_2O_3. The plate was examined after 32 days and found to contain many α-tracks with an equivalent range in air of 1.12 cm. In an area containing approximately 4000 Sm tracks, 14 long tracks of varying lengths were found. An equal area of unimpregnated portion of the plate showed 35 long-range tracks. This discrepancy is quite understandable. The nitrate solution has an oxidizing effect on a latent image, and it presumably removed the latent tracks existing in the emulsion at the time of impregnation. The 14 long tracks seen with the Sm α-tracks are probably due to impurities either introduced with the Sm or already existing in the emulsion and decaying during the 32 days. Furthermore, all the long tracks which ended in the emulsion could be identified by their lengths as α-particles from U, Th, or Po. If there are long-range particles from Sm they certainly number less than 0.4 percent of the short α-tracks. There is absolutely no evidence for proton emission.

It has been suggested by E. Feenberg[4] that the isotope ${}_{64}Gd^{152}$ may possess long-lived α-activity, having escaped detection on account of its low abundance (0.2 percent).

A number of C2 emulsions (100μ) were impregnated with pure Gd_2O_3 by Ilford Ltd., England, during manufacture. Each $3''\times 1''$ plate contained 38 ± 5 mg of oxide. Plates were developed at the end of 4, 9, and 14 weeks after preparation. It was first verified by further impregnating one of these plates with U and measuring its α-tracks that the stopping power of the emulsion had not been altered appreciably by the introduction of the Gd. Hence 1 Mev, α-tracks (and somewhat lower) could have been distinguished clearly. A few tracks were found in the plates having lengths corresponding to the 2-Mev α-particles from Sm. There was no way of proving from our work whether these actually originated from Sm, but as the number of tracks observed corresponds to a Sm impurity in the Gd of less than 10^{-2} percent, the interpretation seems very likely. No other tracks were found which could not be associated with U or Th contamination or reasonably accounted for as due to cosmic rays. Knowing the weight of Gd per plate, the duration of exposure, and the area scanned, it may be said that the half-life of ${}_{64}Gd^{152}$ must be greater than 10^{15} years and is probably greater than 10^{16} years. These figures can be converted for the other isotopes of Gd knowing their relative concentrations, and hence limits can be placed on their half-lives also. Nothing is gained by exposing longer than about 3 months on account of the fading of α-tracks. It is also unlikely that a large increase can be made in the weight of material introduced into the emulsion without jeopardizing its quality. Hence it seems improbable that the lower limit on half-life quoted above can be increased significantly with the photographic method. The next step in such work must be to use isotopically pure or at least enriched Gd. Assuming a photographic emulsion to be impregnated with a pure isotope, the upper limit of half-life which could be detected by a reasonable amount of scanning is probably of the order of 10^{20} years.

The oxides of Sm and Gd were obtained from Johnson, Matthey, and Company, Ltd., London ("Specpure" Brand). We are indebted to Dr. F. N. D. Kurie for suggesting both these problems. One of us (K.B.M.) acknowledges his Studentship from the Science and Industry Endowment Fund, Commonwealth of Australia.

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[2] J. H. Taylor, Nature 136, 719 (1935).
[3] P. Cuer and C. M. G. Lattes, Nature 158, 197 (1946).
[4] E. Feenberg, Rev. Mod. Phys. 19, 239 (1947).

Erratum: Achromatization of Debye-Scherrer Lines

[Phys. Rev. 73, 1207 (1948)]
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IN the above letter, the relative difference $|\Delta d/d|_R$ of two lattice parameters of the sample giving rise to two lines which are just resolved in the Rayleigh sense should read:

$$\left|\frac{\Delta d}{d}\right|_R=\frac{1.22S}{2F}\cot\theta\cos 2\theta\frac{\cos(\theta m+\alpha)}{\cos(\theta m-\alpha)}.$$

Table of Interplanar Spacings in Angstrom or K.X. Units in Terms of 2θ for Different Target Materials

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July 1, 1948

IN view of the widespread and increasing use of the x-ray Geiger counter spectrometer, tables have been computed to expedite the reduction of the diffraction patterns giving line intensities as a function of 2θ.

The tables given in the Internationale Tabellen zur Bestimmung von Kristallstructuren[1] list the d values at intervals of 0.1θ. This requires the reduction of 2θ to θ and interpolation for d. In addition, the volume is scarce and expensive. The tables published by the Advisory Committee for Aeronautics[2] are prepared expressly for use with a Debye-Sherrer camera and give d as a function of R(mm).

The tables here referred to give d values for Mo, Cu, Co, Fe, and Cr targets between the 2θ values 5.0° and 85.0° inclusive. Every tenth of a degree is listed between 5.0° and 70.0°, every two-tenths between 70.0° and 80.0°, and every five-tenths between 80.0° and 85.0°. Since the argument is in angular units, no reductions are necessary to compensate for different counter-arm lengths, motor rates, etc. The values of the interplanar spacings, d, are computed from the Bragg equation, $n\lambda=2d\sin\theta$, where θ is the glancing angle, λ the wave-length of the diffracted target radiation, and n is taken as unity in this case. The tables are available in angstrom units or K.X. units. In either case, conversion curves are given for all five target materials for various values of 2θ.