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

D. Bohm and E. P. Gross
Princeton University, Princeton, New Jersey
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*

K. K. Keller and K. B. Mather
Physics Department, Washington University, St. Louis, Missouri
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.