

LETTERS

Discovery of radiation belts

Regarding the article "The Earth's Radiation Belts" that appeared in the October issue of *PHYSICS TODAY* I would like to give you some information that is not generally known and might be of interest to you and your readers.

The existence of a belt of moving ionizing particles around the earth was discovered already in 1935 by E. M. Bruins. Its existence was concluded from measurements of the intensity of the cosmic radiation at sea level during a voyage from Amsterdam to Corral (Chile) and was published in Bruins's doctor's thesis "Cosmische stralen in het aardmagnetisch veld" submitted to the University of Amsterdam. This thesis, written in Dutch, was intentionally provided with a rather long summary in English of which I enclose a copy. I call your attention to the sentences in the first paragraph on page 87: "The observed effects may be considered as due to *permanent ringcurrents in space* The currents are flowing at a distance of 2-4 earth's radii." The distance stated by Bruins checks very well with that of the outer Van Allen belt. Bruins is now Lecturer in Mathematics at the University of Amsterdam. Further particulars could be obtained from him.

W. J. Oosterkamp

Philips Gloeilampenfabrieken,

Eindhoven

CONFIRMATION FROM BRUINS: I can give you some more detailed information on the discovery of the radiation belts.

In 1932, just having discovered the lyotropic numbers for colloid chemistry, I was asked by Jacob Clay to assist in unraveling the geomagnetic-cosmic-ray problems.

First of all I repeated Kr. Birke-land's experiment on the forbidden spaces¹ of Carl Størmer, and that very experiment suggested to me the following question: Are there currents flowing in such toroidal surfaces in

space? To answer this question it was necessary to separate the external and internal geomagnetic effects and to study the interrelation of cosmic-ray intensity and magnetic storms.

Then I computed the residual magnetic field remaining after subtraction of the eccentric dipole field, and I extended Størmer's computations up to energies found in cosmic rays.

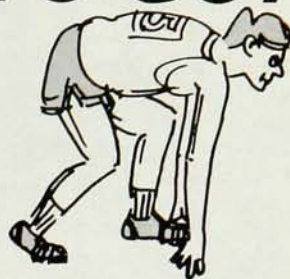
Study of the ring currents showed me the "resonance effect"; that is, the effect whereby the energy limit for cosmic-ray penetration to the earth's surface is lowered—but considerably lowered only if the current is flowing at a distance of the Størmer length unit corresponding to the energy of the incident cosmic ray. Since the direction of the current is uniquely determined by the magnetic dipole, only a lowering of the energy limit can be effected by ring currents.

The residual field indicated to us the Southampton-Capetown shipping routes and the south Pacific line as favorably passing through the field of the six poles of the residual field. Between Southampton and Capetown J. Clay, P. M. Van Alphen and C. G. 't Hooft discovered the "longitude effect" caused by the change of distance to the geomagnetic dipole.² In 1935 I myself went by the south Pacific line to Chile, and I discovered there the "doubling of the equatorial minimum"—contrary to the results of Robert A. Millikan and V. H. Neher³ of the same year (!), 1935. The result was confirmed in 1937 by T. Johnson and D. N. Read.⁴

During this expedition I was favored by the course of the ship, which enabled me to find very accurate data on the "distance effect."

These measurements provided the experimental data for rejecting S. Chapman's 1937 hypothesis⁵ of a "sphere filled with currents of which the intensity varies by $\cos \lambda$, λ the magnetic latitude, flowing very near the earth's surface and giving the relation $\delta M = (2a'^3 - a^3) \delta H$. a'

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is radius of the current sphere; a that of the earth; δM the change in magnetic moment caused, and δH the change in horizontal intensity. The relation is valid for $a' \approx a$. According to the "distance effect" in the Atlantic Ocean such currents had to flow at 3 earth radii—and then the basic assumptions for Chapman's approximation are not valid any more. This is stated in my thesis, pages 79 and 80.

Diminution of cosmic-ray intensity occurring during magnetic storms can be due only to a diminution or vanishing of ring current! As early as 1935 we started in Amsterdam a continuous registration of cosmic-ray intensity, and very soon it was clear that some magnetic storms influence the hard rays but not the weak rays—a seemingly absurd result that is easily explained by the resonance effect and a decrease of permanent ring currents: Only a decrease of the current flowing at the Størmer length for the incident cosmic rays can influence them and cause a diminution of intensity. I prepared my thesis for the doctorate. My statement on permanent ring currents met with skepticism. So I postponed presenting my thesis to the Amsterdam faculty until I should find a storm in which *all* rays showed a lowering of intensity. This storm occurred on 25 Jan. 1938. Immediately afterward I presented my thesis and obtained the DSc cum laude on 30 March 1938.

From the energy of the influenced rays the radius of the current influencing them can be computed. They varied from 2 to 4 earth radii.

As to the particles forming the ring currents, the normal cosmic-ray intensity of rays in the range $4-60 \times 10^9$ eV did not seem to provide the necessary current intensity. This problem was solved easily by indicating that particles of all energies contribute to the ring current. Moreover if they are not following some periodic orbit (as in the nonperiodic trajectories in a nearly isotropic radiation at great distances), the radial components of the trajectories must cancel magnetically, and for all charges and all particles the azimuthal effects are added, and the

stream always corresponds to a current of the same sign (thesis page 3).

I intentionally avoided the term "trapping of low-energy particles" because also in a unipole field the trajectories show the same "optical illusion." One sees the particles as being attracted toward the unipole. The trajectories are, however, geodesic lines on a cone of revolution with its vertex at the unipole. And nobody would agree if one said that a particle moving along a straight line in a plane is attracted by a fixed point in the plane; the distance is simply decreasing and increasing again. There are no orbits—periodic trajectories—in the unipole field! It is well known that in the dipole field, orbits—periodic trajectories—are possible but only if the Størmer integration constant γ satisfies $0 > \gamma > -0.78856$, and the periodic trajectories known in the dipole field are all unstable. So in this case too one should be very careful with the picture: "trapping of low-energy particles."

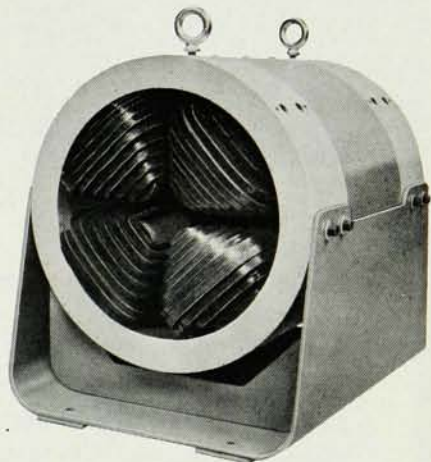
The instruments that I used to prove the existence of permanent ring currents were photographed, and the photographs were printed in the Proceedings of the Royal Academy of Amsterdam, 26 Feb. 1938. As you can see from this, it is not necessary at all to have expensive satellites to measure "on the spot"; three cylinders, costing a few dollars, filled with argon and a few tons of scrap steel of the artillery works were all I needed—in addition to patience.

This research was interrupted by the second world war. But in the time of no light, no electricity, no coal, no gas and hardly any food, I still could continue my studies on the history of mathematics. These caused, immediately after the war, a contact with the Mission Archéologique en Iran, Paris, which asked my coöperation for the edition of the Susa mathematical cuneiform texts. They were published after 12 years in 1961, and I went to Baghdad as a UNESCO expert for the organization of the University of Baghdad. There I could also continue the cuneiform studies, and on my way back in 1954 I started the studies of a Greek mathematical codex in Istanbul (edited 1964). These studies led to a nomination with the Académie Internationale d'Histoire des Sci-

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ences, and in its turn this nomination led Edward Penkala to trace my scientific work.

Penkala discovered last year that E. M. Bruins of the history of mathematics, the Assyriologist, the mathematician of the theory of invariants, the editor of Greek manuscripts, the colloid chemist and he who wrote his thesis on results of a cosmic-ray expedition to Chile, proving in his work on magnetic storms the existence of permanent radiation belts at 2-4 earth radii, was one and the same man.

I can only say that in 1938 I did nothing to keep secret my answer on the question I put to myself in 1932 concerning the radiation belts. I sent about 400 copies of my thesis all over the world, many of them to the United States, to libraries and scientific workers on cosmic rays. Since 1938 it is only a *tolle lege* ("take up and read"): Currents can only lower the energy limit. A decrease of cosmic-ray intensity correlated with magnetic storms must be caused by diminution of normally existing currents. For nothing can diminish that did not exist before.

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2. J. Clay, P. M. van Alphen, C. G. 't Hooft, *Physica* 1, 829 (1934).
3. R. A. Millikan, H. V. Neher, *Phys. Rev.* 47, 205 (1935).
4. T. Johnson, D. N. Read, *Phys. Rev.* 51, 557 (1937).
5. S. Chapman, *Nature* 140, 423 (1937).

E. M. Bruins

Amsterdam-Z.-Holland

How long to live

I was delighted by the intrusion of the physicist, Gerald Feinberg, into the domain of the life sciences with his provocative article in the November issue on the prolongation of life. Such behavior for natural scientists is fortunately not unprecedented in the history of medicine. I, as a physician, also find his reasoning compelling. The preservation of complex biomolecular structure at low temperatures has not only important practical

medical advantages but even more profound biological implications, so well expressed by Feinberg. The point not emphasized enough by him is that, with a concerted effort, including those of physicists, this fascinating problem might be solved within our lifetime.

Peter Gouras

Washington, D. C.

I read with interest and dismay Gerald Feinberg's article "Physics and Life Prolongation." In reply, I wish to caution Feinberg and the members of a small but growing movement that (1) cryogenics as a way to suspended animation and (2) suspended animation as a way to death postponement (the semantic invert of life prolongation) may prove, in the long run, to be unwise. I do not wish to argue the scientific plausibility of the cryogenic approach to suspended animation—though I doubt that *salvage* from the frozen state will not leave scars—but I do wish to point out the dangers of an idea that involves cryogenics, suspended animation and unreasonable optimism for the future—especially if it should gain widespread acceptance by the public.

Although Arthur Clark's law is a very interesting bit of wisdom, it can be a semantic "foot-in-the-door" to justify a great deal of mission-oriented research. The issue is not whether the goal of that research can be accomplished, but, rather, whether it has a potential application in the world of the public. At this point the originator of the idea under study faces, in addition to a scientific responsibility, a moral responsibility.

I think Feinberg has not only pre-empted a field that should be left mainly to the analytical biologist but irresponsibly suggested that, "Successful methods for freezing, storing and reviving humans would evidently have widespread application."

It would not be hard at all for the civil-minded scientist to think of several sociological and economic reasons why widespread freezing of humans should not be encouraged. It is possible that eventually large numbers of perfectly healthy persons may wish just to travel to the future to benefit from what they believe will be a better life. So far no one has considered

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