$$a \simeq 10^{-1} A^2 \omega_s,$$

where A is the relative amplitude of the varying field and ω_s the frequency of scattering of a particle by magnetic irregularity. For $A \simeq 10^{-1}$ and $\omega_s \simeq 10^{-2}$ sec^{-1}, the characteristic time for acceleration is estimated as about a day. This seems to explain the gain of relativistic energy about a day after the rapid magnetic disturbance begins, in accordance with (3). The acceleration to non-relativistic energy, as expected in (2), should take place earlier.

The acceleration hypothesis appears to be consistent with Simpson's observation[5] that the intensity increase begins near the equator, as described in (3), because the increase of pitch angles takes place in association with the increase of the transverse energy.

Finally, a brief comment will be made concerning the non-adiabaticity. In defining the adiabatically invariant quantity, one cannot simply take $p^2 \sin^2\theta / H$ but should take the invariant integral $J = \oint p dq$.[6] This deviates from the conventional one by ΔJ, so that the invariance of J does not always lead to the mirror reflection at a definite position. This implies that the turning point is displaced according to $\Delta J/J$; if the energy of a particle changes, the so-called non-adiabaticity results in the drift of a particle from one magnetic line of force to another. If the energy change is negligible, the displacement of the turning point may be only an effect of interest. The displacement depends on the phase of the gyrating motion and is predictable if one follows the trajectory of a particle. Actually, however, a weak perturbation may cause phase changes, so that the value of $\Delta J/J$ may distribute at random. After n oscillations the particle may be lost from the mirror trapping, provided

$$n(\Delta J/J)^2 \simeq 1.$$

According to our rough estimate[6], $\Delta J/J \simeq \rho/R$, where ρ is the gyration radius and R the radius of curvature of a magnetic line of force. For a proton of about 100 MeV in the inner belt, therefore, the trapping time against the non-adiabaticity is estimated to be of the order of a month. Although I cannot give any quantitative result, I hope this would make clear the effect of the so-called non-adiabaticity.

References

1) S. Yoshida, N. Matuura and T. Nagata: This conference, RB II-2-6.
2) J. R. Winckler: RB II-2-1.
3) Professor Simpson pointed out in his private conversation that the electrons responsible for the intensity increase could be interpreted as due to protons. He also remarked that the increase coincides with a rapid magnetic disturbance.
4) S. F. Singer: This conference, RB II-2-4.
5) J. A. Simpson, C. Y. Fan and P. Meyer: This conference, RB II-2-11.
6) S. Fukui, S. Hayakawa, H. Nishimura and H. Obayashi: This conference, RB II-2-8.

Radiation Belt

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The study of radiation belts substantially adds to the knowledge we are able to acquire, of the properties of cosmic space in the intermediate vicinity of the earth.

At present one can consider it an established fact that the inner radiation belt is evolved by the decay of neutrons from the atmosphere affected by cosmic-ray bombardment. The compositions of the radiations, the energy spectrum of protons and the great permanency of the inner radiation belt are well consistent with the neutron hypothesis.

Mention, however, should be made of one observation that has yet to be accounted for.

In 1960 during the flight of the Soviet second space ship protons of the inner radiation belt were registered in the region of the Brazilian magnetic anomaly. As Dr. Rothwell pointed out in the discussion during the flights of the American artificial satellites in 1958 no inner radiation belt was detected at altitudes below 500 km even in the same region of Brazilian anomaly. This may be regarded as an indication at some changes of the inner belt with time, which cannot so far find an adequate explanation.

The inner radiation belt is confined to the region over equatorial areas that is near to the earth.

Evidently, on the magnetic force lines more distant from the earth there are rather strong variations of the magnetic field. As a result, the adiabatic invariants are disturbed and the protons produced from neutron decay cannot exist there for very long time. The variations should also cause particles to accelerate. We have discovered the outer radiation belt which is likely to be brought about by some acceleration mechanism somewhere not far from the earth. Our measurements show that the outer radiation belt cannot be explained by the neutron hypothesis.

In the 1960 flights of space ships we measured bremsstrahlung created by electrons with energies of some hundreds of kev. The electron flux turned out to be so great that all the outer radiation belt would have to disappear in 10^6-10^8 seconds. The calculation was made in the following way. Taking into consideration the Coulombian scattering of electrons at small altitudes, by the formula analogous to that of *Christophilos* one can calculate the *velocity* of the drift to the earth of mirror points, i.e. points where particles are reflected from regions with a great magnitude of magnetic field strength. When the electron flux of the outer radiation belt at small altitudes (200–300 km) and the velocity of drift to the earth of their mirror point are known, it is possible to calculate the number of electrons leaving the outer belt and thus derive the above-mentioned time of life for the belt. It should be noted that due to the sharp decrease of atmosphere density with altitude, the drift of mirror points attributed to the Coulombian scattering at high altitudes will be very small. To account for the stability of the outer radiation belt one should, therefore, assume the existence at high altitudes of the non-Coulomb drift of mirror points. This drift may be effectuated by the *oscillations* of magnetic bottleneck (mirror-point) with the frequencies over 10 c/s. Thus there are grounds to suppose that such frequent *oscillations* of magnetic field do exist.

Another reason why the outer radiation belt cannot be accounted for by the decay of albedo neutron is that part of the electrons of the outer belt are of great energies than the electrons from neutron decay can be. In the flight of the Soviet second space probe, the electron spectrum was measured, which showed that there are electrons of energies over 10^6 ev, that is considerably greater than the energy of electrons from neutron decay.

All the data agree in that to account for the outer belt one should search for a mechanism of electron acceleration near the earth.

We believe that apart from the accelerating mechanism that operates during earth storms, there is to be another mechanism for electron acceleration at the time when there are no storms. The comparison of the results of measurements made during the flights of space probes in the magnetically quiet time show that the intensity of radiation in the outer belt is constant, at least within the accuracy of 50%. Should the acceleration take place during magnetic storms only, the radiation intensity in the outer belt would greatly depend on the time that has elapsed since the last storm and on the intensity of this storm.