This circumstance apparently points to a more complicated character for the interaction of rotons with vortices which cannot be reduced to simple scattering (in a $\mathbf{p}\cdot\mathbf{v}_s$ field). Apparently, for rotons passing by a vortex at small distances from its axis, processes having the character of "strong interactions" take place, which bring about a momentum transfer of the order of the total momentum of the roton. Several processes can take part in the creation of this interaction, such as the transition of a roton to a "bound" state and subsequently its emission back to a free state (for $\mathbf{p}\cdot\mathbf{v}_s < 0$ the field in which the roton finds itself looks like a field of attraction, and a finite motion in it is possible with an energy $\epsilon < 0$; a roton can go over into such an orbit with the simultaneous excitation of vortex oscillations, and can leave by absorbing the energy of these oscillations.* The "eroding" of a vortex due to its natural oscillations can also play an important role. An investigation of all these effects, however, is very involved, and to a certain extent becomes indeterminate because all of the characteristic lengths turn out to be comparable with atomic distances.

It is natural to try to describe this interaction phenomenologically by introducing a temperature-independent effective vortex diameter ("width") a, corresponding to the transfer of the total momentum of a roton to a vortex. The result is the addition of a term $0.7\,a\rho_n\sqrt{kT/\mu}$ in D. This process makes no contribution to D′; on the contrary one has to introduce a factor $\varphi(a) < 1$ in D′ to account for the corresponding "cut-off" of the integral over the range of distances in the calculation of this quantity. Satisfactory agreement with Hall and Vinen's measurements (shown by circles in the figure) is obtained for $a \cong 10$ Å (with $\varphi(a) = 0.6$).† This value is somewhat larger than one would naturally expect. It should be emphasized, however, that it is extremely sensitive to the choice of the experimental values of B. In connection with this situation it would seem to be very desirable to carry out further measurements, particularly at lower temperatures.

Values of B′ calculated from Eq. (3) (for the indicated value of a) are also shown in the figure; it should be pointed out that they are very sensitive with repect to the value of the factor $\varphi(a)$. It would also be desirable to obtain experimental data for this quantity (there are none at present).

We express our thanks to Academician L. D. Landau for a discussion of the problems under investigation.

[1] H. E. Hall and W. F. Vinen, Proc. Roy. Soc. 238A, 204 (1956)
[2] H. E. Hall and W. F. Vinen, Proc. Roy. Soc. 238A, 215 (1956)
[3] L. D. Landau and E. M. Lifshitz, Dokl. Akad. Nauk S.S.S.R. 100, 669 (1955)

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ON THE CONSERVATION OF COMBINED PARITY ‡

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IT has been shown by experiments of Wu and others that in the weak interactions (of the type of β-decay) the parity I is not conserved. It has also been shown that in the weak interactions there are two possibilities: either I, C, and T are separately not conserved, and only their product is conserved, or there is

*It can be shown that this process ought not to lead to the appearance of a large longitudinal friction force (along ω). The point is that the longitudinal component of the momentum lost by the roton is transerrred to quanta of oscillations of the vortex filaments, belonging to the normal fluid, and consequently transfers of momentum from the normal fluid to the superfluid do not take place.

†The value of this factor depends essentially on the method of "cut-off," that is, on the location of the segment a relative to the axis of the vortex. Ths value of φ given above corresponds to placing this segment off to one side of the axis, where the attaction of a roton takes place.

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conservation of the combined parity IC introduced by Landau[1] and of T. On the other hand, it is believed that in strong and electromagnetic interactions I, C, and T are separately conserved.

We propose and examine the following hypothesis: In the construction of the Lagrangians of the strong, electromagnetic, and weak interactions of elementary particles it is necessary to require invariance with respect to IC and T, i.e., the conservation of only the combined parity. In some cases the conservation of the combined parity leads to the conservation of spatial parity; in other cases spatial parity is not conserved. The Lagrangian of an interaction invariant with respect to the operation IC can be written in the form of two terms, $L = L_1 + L_0$, where L_0 is invariant with respect to spatial reflection and L_1 is responsible for nonconservation of the parity I.

We confine ourselves to the consideration of the strong and electromagnetic interactions, regarding the connection between spin and statistics as already established. The renormalized and gauge invariant Lagrangian of the interaction of the nucleon field with the electromagnetic field and with fields of particles of spin zero, invariant with respect to the operation IC, has the following form

$$L(x) = e\bar{\psi}_p\gamma_\mu\psi_p A_\mu + g_1(\bar{\psi}_p\gamma_5\psi_n\Phi^* + \bar{\psi}_n\gamma_5\psi_p\Phi^*) + g_2'\bar{\psi}_p\gamma_5\psi_p\Phi^0 + g_2''\bar{\psi}_n\gamma_5\psi_n\Phi^0$$

$$+ ig_3(\bar{\psi}_p\psi_n\Phi - \bar{\psi}_n\psi_p\Phi^*) + g_4(\bar{\psi}_p\psi_n\varphi + \bar{\psi}_n\psi_p\varphi^*) + g_5'\bar{\psi}_p\psi_p\varphi^0 + g_5''\bar{\psi}_n\psi_n\varphi^0 + ig_6(\bar{\psi}_p\gamma_5\psi_n\varphi - \bar{\psi}_n\gamma_5\psi_p\varphi^*). \quad (1)$$

Here there are also two kinds of bosons, transforming under the operation C in the following way:

$$\varphi^{0\prime}(x) = \varphi^0(-\mathbf{x}, x_4), \quad \varphi'(x) = \varphi^*(-\mathbf{x}, x_4), \quad \Phi'^0(x) = -\Phi^0(-\mathbf{x}, x_4), \quad \Phi'(x) = -\Phi^*(-\mathbf{x}, x_4). \quad (2)$$

Besides the vertex coefficients e, g_1, g_2', g_2'', g_4, g_5', g_5'' which exist in the case in which I and C are separately conserved, in our case there have appeared the additional coefficients g_3 and g_6. We note that all the coupling constants $e, g_1, \ldots, g_6$ are real, and the matrices γ are those of Feynman's convention.

In the case of quantum electrodynamics, because of the condition of gauge invariance, the requirement of invariance with respect to the operation IC leads automatically, without the neglect of any terms of the interaction Lagrangian, to invariance with respect to I and C separately, i.e., to the conservation of spatial parity. In the case of meson theory, however, there appear terms leading to nonconservation of I, which gives the possibility in principle of an experimental check of our proposed hypothesis.

Thus while Lee and Yang[2] regard processes in which parity is not conserved as an exception to a general rule, caused by the participation of two-component neutrinos in such processes, we start from a general law of the conservation of the combined parity, and in the special case of the electromagnetic interaction there is at the same time conservation of the spatial parity.

Let us look into the question of experimental checks of our hypothesis. As was shown by Landau,[1] in the case of conservation of the combined parity particles cannot have dipole moments. It is shown above that in the case of electrodynamics the requirement of invariance with respect to IC automatically leads to conservation of I and C separately. Therefore the experimental data from the field of atomic spectroscopy cannot contradict our hypothesis. Thus of the experiments considered by Lee and Yang,[3] which point to the conservation of spatial parity in the strong interactions, there remain nuclear spectroscopy and experiments to measure in double scattering an asymmetry with respect to the plane of the first scattering when protons interact with nuclei of spin zero. The transition amplitude for such a process contains a term that violates the conservation of spatial parity, which leads to the appearance in the second scattering of an up-down asymmetry with respect to the plane of the first scattering. The contribution of the terms responsible for the violation of parity is small; Chamberlain and others[4] have shown that this asymmetry is not larger than 1%. Therefore it is necessary to carry out more precise experiments to measure the above-mentioned asymmetry to test the hypothesis here proposed.

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[1] L. D. Landau, J. Exptl. Theoret. Phys. (U.S.S.R.) 32, 405 and 407 (1957), Soviet Phys. JETP 5, 336 and 337 (1957).

[2] T. D. Lee and C. N. Yang, Phys. Rev. 105, 1671 (1957).

[3] T. D. Lee and C. N. Yang, Phys. Rev. 104, 254 (1956).

[4] Chamberlain, Segré, Tripp, Wiegand, and Ypsilantis, Phys. Rev. 93, 1430 (1954).

Translated by W. H. Furry
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