CBPF-NF-014/96

A Possible Explanation of the CP Puzzle

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ABSTRACT

The problem of mirror-reflection symmetry (MRS) and time-reversal symmetry (TRS) in our world is discussed.

The opinion is expressed, that well-known experiments on parity violation and CP-violation can be treated as signals of some new, yet unknown, level of matter.

An hypothesis, which can be used as a base for some future model or theory is formulated. In the framework of this hypothesis, experiments which demonstrate parity violation or CP-violation do not contradict MRS or TRS conservation.

Key-words: Mirror-reflection symmetry; Time reversal symmetry; New level of matter.

Pacs numbers: 11.30.Er, 12.90.+b

The hypothesis of possible parity violation was suggested in 1956 by Lee and Yang [1] and then experimentally confirmed by Wu with collaborators in 1957 [2]. CP-violation was experimentally discovered in 1964 by Christenson, Cronin, Fitch and Turlay [3]. Since then, these phenomena remain unsolved puzzles in modern physics. Very probably at present, especially for the younger generation of physicists, some witnesses are needed to confirm that violation of P and CP are puzzling phenomena. The very direct and open opinion of Feynman about parity violation can be found in his book [4]. And very nice sketch of events following discovery of CP-violation is presented by Cronin in his Nobel lecture [5].

Speaking here about MRS I will use the definition given in Ref. [6]. Namely I assume that the symmetry exists if the following rule is valid:

The probability for any process equals the probability for the mirror image of that process.

Similarly, speaking about TRS, I assume it exists if:

The probability for any process equals the probability for the time-reversed image of that process.

The general opinion is that present experimental and theoretical results contradict MRS conservation. A typical statement, reflecting this general opinion can be found, for example, in the book of R.Sachs [7].

But there is another view in which parity still can be considered an exact symmetry.

We start with a short history of exactly conserved parity. The first general statement about conserving parity was expressed by Lee and Yang in Ref. [1]. They said that parity may still be conserved if some partners of the usual particles exist which exhibit opposite asymmetry. Wigner [8] suggested an hypothesis, according to which each antiparticle is an exact mirror copy of particle. In this case the experiment of Wu does not contradict MRS and parity is conserved. But the main psychological barrier to accepting this idea is that electric charge in this case is pseudoscalar, not scalar [9]. In spite of lack of experimental data about the internal structure of electric charge, the general opinion is that it is a scalar [10].

Some possibilities for explanation of the experimental data without violation of left-right symmetry were considered by Yu.Shirokov [11]. He claimed that a particle under spatial inversion and temporal reversal is transformed into some other state (e.g. into an antiparticle).

But it became clear after 1964 that antiparticles are not mirror copies of particles, hence, some other candidates for mirror counterparts of usual particles are needed for parity conservation theory. Hypothetical mirror particles were described at first in a paper of Kobzarev, Okun and Pomeranchuk in 1966 [12]. According to their hypothesis each usual particle has a mirror twin with the same mass. Mirror particles have their own electric charges and their own weak and strong interactions such that they interact with particles of our world only gravitationally and through some new superweak field. But in the framework of their hypothesis, MRS still does not exist. A weak interaction Lagrangian remains both P- and CP-non-invariant, but now it is invariant relative to the CPA-transformation, where A is a new operation, transforming usual particles into mirror ones, and vice versa. Respectively, all the charges are scalars.

A very interesting example of parity conservation theory was presented by M.Pavsic

[13]. His main idea is that all elementary particles have internal structure with internal spatial and temporal degrees of freedom. Hence to fulfil total space inversion (P_T), one has not only to make usual external inversion (P_E), but also internal inversion (P_I). In other words, for the total description of an elementary particle we have to introduce new variables corresponding to these internal degrees of freedom. Effectively, this is done by adding to the standard set of variables (coordinate, momentum, spin) two new parameters α and τ. Parameter α has two discrete values: $+1$ and -1, and internal spatial inversion changes the sign of this parameter. Parameter τ also has the same two discrete values $+1$ and -1, and again internal time reversal changes the sign of this parameter.

One more left-right symmetric theory was considered by Foot, Lew and Volkas [14]. The theory also includes mirror particles with their own weak, strong, and electromagnetic interactions. The question about non-scalar charges is not discussed in the paper.

It might be said that the difference between parity violating (like, for example [12]), and parity conserving ([14]) mirror particle theories is not very large. Namely, the difference is just in the name of the operator; what is named operator A in one paper is called operator P in another.

But it should be emphasized that the difference is far from being just formal; a parity conserving theory may lead us to the unfolding of the internal structure of quarks and leptons.

Experiments demonstrating CP-violation conclude that the amplitude of the transition $\overline{K}^0 \rightarrow K^0$ is greater than the same for the transition $K^0 \rightarrow \overline{K}^0$. This phenomenon does not contradict directly neither MRS nor TRS validity. It only demonstrates some strange inequality between matter and antimatter in our world. And, assuming validity of the CPT-symmetry, violation of CP-symmetry means also violation T-symmetry. Then processes, demonstrating absence of TRS, like e.g. electric dipole momentum can be observed. Taking into account that classic analog of spin is rotation, one may say, that such thing as time-reversal image of rotating neutron with electric dipole momentum never can be observed.

The point of interest is that P- and CP-violation phenomena can be considered as a manifestation of some new level of matter, more primary than quarks and leptons. Let's consider the mirror particle hypothesis, assuming that mirror particles are true mirror images of usual particles. In this case the MRS exists in the exact sense of the word, and electric and other charges can not be scalars, since simple reflection of spatial axes transforms each charge into another kind of charge.

But, if charge changes its property at mirror reflection, it's quite natural to assume that it has some space-time structure. Hence, some new, more fundamental level of matter exists and our particles and antiparticles, together with their mirror counterparts, are just made of the same pre-particles, or preons, just as left and right molecules of sugar are made of the same atoms. And what we call electric and other charges is just the result of specific movement of these preons. The idea of electric charge being the result of some movement is not new having appeared in early Kaluza-Klein models.

At present nobody can suggest a quantitative model of quarks and antiquarks made of these moving preons, but one can point out some features of such a future model. There could be one or more types of preons, but none of them possess any of the well-known charges (electric, weak, strong). As a result of their interaction they make four different kinds of objects, namely, quarks, antiquarks, mirror quarks, and mirror antiquarks. The system representing a quark is the mirror copy of a system representing a mirror quark and time reversal transforms both quark and mirror quark into antiquark and mirror antiquark, respectively.

This last feature was already presented in the early Kaluza-Klein model. Electric charge in the model arose as a result of movement of the particle along the additional (compactified) fourth space dimension. And the direction of this movement defined the charge of the particle. So the electron was exactly the same as a positron observed in the reversed time frame.

Usual and mirror particles and their antiparticles can be described as states with inner degrees of freedom (as it was done by Pavsic [13]). Let $\Psi_1(x,\alpha,\tau)$ and $\Psi_2(x,\alpha,\tau)$ be wave functions, describing particles and antiparticles, whereas wave functions $\Psi_3(x,\alpha,\tau)$ and $\Psi_4(x,\alpha,\tau)$ describe mirror particles and antiparticles, respectively. All four of these functions are neither spatially, nor temporally symmetrical. Instead of this, the following relations take place

$$\Psi_1(x,\alpha,\tau) = \Psi_3(x,-\alpha,\tau) \tag{1}$$

$$\Psi_2(x,\alpha,\tau) = \Psi_4(x,-\alpha,\tau) \tag{2}$$

$$\Psi_1(x,\alpha,\tau) = \Psi_2(x,\alpha,-\tau) \tag{3}$$

$$\Psi_3(x,\alpha,\tau) = \Psi_4(x,\alpha,-\tau) \tag{4}$$

Evidently, if equations (1)–(4) are valid for all leptons and for all quarks (both usual and mirror), then what we call P-violating and T-violating phenomena look quite natural and understandable. And inequality between matter and antimatter now is not strange, because at the same time we observe symmetrical inequality between mirror matter and mirror antimatter.

Within this hypothesis such T-violating phenomenon as neutron (or any other particle) with electric dipole momentum does not contradict TRS because observing it in the reversed time we see the same picture, as observing antineutron in the direct time.

More generally, on the preon level all phenomena clearly demonstrate the validity of both MRS and TRS. We conclude that these symmetries seem to be violated in our experiments only because so far we have only observed two of the four kinds of composite systems. Physicists of the 19-th century could similarly claim a violation of MRS when observing the rotation of the plane of linearly polarized light passing through a sugar solution. As long as the second form of the sugar molecule were not yet discovered, the quality of the proof of their statement would be precisely as good as the quality of proof of parity violation in the 20-th century.

The main idea expressed in this paper can be stated in the following way:

Experimental data demonstrating CP-violation forces us to guess that there is something moving inside quarks and leptons. And the only difference between a quark and its respective antiquark is the direction of the movement of this "something".

Any theory which incorporates this idea will be free from the CP puzzle.

Acknowledgements. The author is grateful to Dr. V. Nikitin (JINR) and to Dr. D. Bardin (JINR) for very helpful discussions and support. Discussions on the last stage of work on the paper with Dr. A. Demichev (Moscow State University) were very fruitful and pleasant.

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[3] J. H. Christenson, J. W. Cronin, V. L. Fitch, R. Turlay, Phys. Rev. Lett. **13**, 138 (1964)

[4] "This is a mystery that no one has the slightest idea about yet".

R. P. Feynman, *The Character of Physical Law* (Penguin Books, 1992) p. 107.

[5] "We must continue to seek the origin of the CP symmetry violation by all means at our disposal. We know that improvements in detector technology and quality of accelerators will permit even more sensitive experiments in the coming decades. We are hopeful, then, that at some epoch, perhaps distant, this cryptic message from nature will be deciphered."

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[6] K. Gottfried, V. Weisskopf, *Concepts of Particle Physics* (Clarendon Press, Oxford, 1984) Vol. 1, p. 25.

[7] "Inversion enters into considerations of physics because of another common perception - that right- and left-handedness are matters of convention rather than of substance. Thus until Lee and Yang (1956) proposed and Wu and others (1957) confirmed a contradiction to this assumption, inversion was included among the transformations expressing the isotropy of space, and right- and left-handed coordinate systems were taken to be indistinguishable. Either implicitly or explicitly, the dynamic laws were assumed to be invariant under inversion."

R. G. Sachs, *The Physics of Time Reversal* (The University of Chicago Press, Chicago, 1989), p. 2.

[8] E. Wigner, Rev. Mod. Phys. **29**, 255 (1957)

[9] The hypothesis of Wigner by no means coincides with the CP-conservation hypothesis. The hypotheses differ in the main point. Wigner recognizes the antiparticle as the true mirror counterpart of the particle, while for the CP-conservation hypothesis the mirror counterpart of neutrino simply does not exist. In other words, Wigner is looking for an answer to the very relevant questions: "*Why* is CP conserved? *Why* does the operation C produce the same effect as the very different operation P ?".

[10] It is just remarkable that Pauli has no doubt that the origin of such a fundamental entity as electric charge can be clarified by some mysterious convention.

"Nach der üblichen Auffassung (Konvention) ändert bei der Operation P die elektrische Ladung ihr Vorzeichen nicht, so dass die elektrische Feldstärke ein axialer Vektor ist."

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