On an additional realization of supersymmetry in orthopositronium lifetime anomalies

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Abstract

Expansion of Standard Model for the quantitative description of the orthopositronium lifetime anomalies (from QED to supersymmetric QED/SQED) allows to formulate experimental tests of supervision of additional realization of the supersymmetry in final state of the positron beta-decay of the nuclei such as $^{22}$Na, $^{68}$Ga ($\Delta J^\pi = 1^+$). The experimentum crucis program is based on supervision of the orthopositronium “isotope anomaly”, on the quantitative description of the “$\lambda_T$ - anomaly” and will allow to resolve the alternative as results of the last Michigan work (2003).

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No reliable observations of supersymmetry effects have thus far been reported. Standard Model (SM) concepts suggest that this is due to the presently achievable accelerator energies being not high enough, an obstacle that may be overcome in the nearest future after the start-up in CERN of the new accelerator, the Large Hadron Collider (LHC).

The manifestation of supersymmetry would be signaled by “disappearance” of the energy and momentum carried away by the lightest of the supersymmetric particles [1] (the energy deficit).

It is not inconceivable, however, that supersymmetry effects have already manifested themselves on a conceptually different road which is not associated with ultrahigh particle energies. We are going to show below that an energy deficit can likewise be an experimental criterion of manifestation of an additional realization of supersymmetry beyond the present SM.

It is well known that double application of supertransformation, from the fermion to boson and back to the fermion, transfers a particle to another point in space. This is accepted as nothing more than a mathematical attribute of supertransformations: “…the anticommutator of two spinor generators $Q$ is expressed through the quantity of dimension $m$, namely, through a 4-momentum $p_\mu$, the generator of the four-dimensional displacement

$$\{Q, \overline{Q}\} \equiv Q\overline{Q} + \overline{Q}Q = -2p_\mu \gamma_\mu ,$$
where $\gamma_\mu$ are the Dirac’s 4-matrices. The spinor transformation may be conceived as if a square root of the displacement” [2, p.107]. But it is in this mathematical fact that new physics probably lies hidden.

The proposed program of additional measurements would make use of observation and quantitative description of the lifetime anomalies of orthopositronium ($o$-$Ps$, $^T$Ps), more specifically, of the “isotope anomaly” in neon in the “resonance conditions” (precision comparative measurements yield the $1.85 \pm 0.1$ factor [3]) and of the “$\lambda_T$-anomaly” (precision absolute measurements yield $\Delta \lambda_T/\lambda_T \simeq +/0.19 \div 0.14/\%$), see references in [4]).

Progress reached in the quantitative description of the orthopositronium lifetime anomalies [5] permits us to consider displacement as a structural element of a non-stationary long-range non-Newtonian/non-Coulombian type for all physical interactions, including long-range (non-stationary!) baryon charge interaction in the final state of positron $\beta$-decay of nuclei of the type of $^{22}$Na and $^{68}$Ga ($\Delta J^\pi = 1^+$). In so doing, $\beta^+$-decay is considered as a topological quantum transition (TQT), and the final state of the nucleus exists during the time $\tau_\mu \sim 2 \cdot 10^{-5}$ s against the background of a “defect”, a limited macroscopic volume of a crystal-like space-time structure (the “long-range atom”). Displacement plays here the part of the constant of a three-dimensional cubic lattice, but a 3D structure may be conceived of as a discrete one-dimensional structure (Hamiltonian cycle over $N^{(3)}$ “sites”) during the time $\tau_\mu$ [6]. This model permits one to calculate the total number of sites in the “atom” (the number of steps in the cycle), $N^{(3)} = 1.302 \cdot 10^{19}$. The “atom” can be differentiated into a “nucleus” (the number of “sites” $\pi = 5.2780 \cdot 10^4$) and a “shell”. All sites in such an “atom” are identical in the full set of charges of all physical interactions while differing (in the “nucleus” and the “shell”) in their dynamic manifestations [5, 7].

The success of this model consists not only in that it is capable of a quantitative description of the “isotope anomaly” (factor 2) and of the “$\lambda_T$-anomaly” of $o$-$Ps$, but in its having expressed to within $\sim 10^{-3}$ the double-valued ($\pm$) Planckian mass through the fine structure constant $\alpha$ [6]

$$\pm M_{Pl} = \pm \sqrt{\frac{(\hbar c)^3}{4\pi \alpha}} \simeq N^{(3)} \cdot (|\pm m_p|+(\pm m_e)| \simeq \frac{\sqrt{3}}{\pi(2)^{3/2}} \cdot (|\pm m_p|+(\pm m_e)| \simeq 2.179 \cdot 10^{-5} g.$$  

The issue of the existence of new long-range forces was formulated in the SM: theory has considered the consequences of a possible existence of long-range interactions, of both abelian and non-abelian type [2, pp. 122-123], and on the experimental side, a high-precision search for a fundamental spin long-range interaction has yielded a negative result [8].

The present SM offers a fairly loose treatment of the null energy condition (NEC) as absolute forbiddenness of physical manifestation of the negative energy (mass) sign. Note, however, that the concept of negative energy (mass) density of the compensating field does not involve any difficulties of a fundamental nature.

In TQT conditions, the argument of impossibility of a physical manifestation of spacelike structures likewise loses its persuasiveness (causal anomalies).
A basic possibility of overcoming this forbiddenness is offered by the concept of "... a complete relativity, i.e., of equivalence of all velocities (except for the light itself)", which allows the existence of "non-electromagnetic long-range interaction of bodies with a nonzero average spin density" [9] (cf. [8]).

Complete relativity (i.e., coexistence of locality and non-locality) is formulated in other terms (A. L. Zelmanov’s method of chronometric invariants) in the theory of zero-space and zero-particles in a generalized space-time, which was developed independently as an expansion of the General Theory of Relativity [10, 11].

The orthopositronium anomalies have created a new situation. Removal of these fundamental limitations in an analysis of the nature of the o-Ps anomalies provides a justification for simultaneous physical realization in the final state of $\beta^+\beta^-$-decay (or, treated in a broader sense, in the final TQT state [7]) of positive Planckian mass as vacuum-like states of matter/VSM [12] (+ $M_{Pl}$: a VSM "microstructure") and of the compensating "C-field" (the "mirror Universe", $-M_{Pl}$) [5-7].

All this can also be treated in the context of non-abelian-type long-range forces: "... Yang-Mills theory with zero mass obviously does not exist, because a zero mass field would be obvious; it would come out of nuclei right away. So they <meson physicists> didn’t take the case of zero mass and not investigate it carefully" [13] (cf. [2, pp. 122-123]).

At the University of Michigan (Ann Arbor), the last measurement of the o-Ps annihilation rate has been carried out; the researchers report now on the complete agreement between the experimental value, $\lambda_T(\text{exp}) = 7.0404(10)(8) \mu s^{-1}$, and the value calculated in the frame of QED, $\lambda_T(\text{theor}) = 7.039979(11) \mu s^{-1}$ [4]. These measurements were performed by a different technique, namely, a dc electric field of $\sim 7$ kV/cm was introduced into the measurement cell, and, therefore, the final conclusion of the (new) Michigan group can hardly be considered unambiguous, because it disregards the "isotope anomaly" of o-Ps. For this reason, the researchers could not include the additional action of the electric field on the observed o-Ps self-annihilation rate $\lambda_T(\text{exp})$ [6], besides the provisions they undertook to ensure complete o-Ps thermalization. The additional action of the electric field $E \sim 7$ kV/cm oriented parallel to the force of gravity should suppress the excess $\Delta \lambda_T/\lambda_T \simeq (0.19 \pm 0.14)\%$ over the calculated value $\lambda_T(\text{theor})$, which had been reported earlier by the Michigan group and referred to quantitatively as macroscopic quantum effect (the "$\lambda_T$-anomaly" ref. [5-7]).

This is why rejection [4] of the conclusions drawn from the earlier high-precision $\lambda_T$ measurements does not appear unambiguous.

The uncertainty we are presently witnessing can be resolved only by performing a program of additional measurements.

Consider the scheme of a Gedanken experiment for a measuring cell filled with a gas (Fig. 1).

Could one substantiate a program of comparative measurements which would yield as a final result the doubling (factor 2) of the parameter V to be measured
Figure 1: Scheme and the result of a Gedanken experiment with an electric field in the Earth laboratory. The measuring cell is filled with gas. $\mathbf{E}$ – orientation and dc voltage of an electric field; $V$ – is the value of the parameter to be measured.

with the external dc electric field orientation changed from horizontal to vertical? This would be certainly impossible within the SM. An analysis of the $o$-$Ps$ anomalies within the concept of spontaneously broken complete relativity [5-7] opens up such a possibility; indeed, restoration of the symmetry under discussion “should be accompanied by doubling of the space-time dimension” [9].

The uniqueness of orthopositronium dynamics (virtual single-quantum (!) annihilation, CP-invariance) make it an intriguing probe to double the space-time (see [5]).

Unlike gravity and electricity, the new long-range interactions become manifest only in transient (non-stationary) conditions, as a generalized “displacement current” of all physical interactions (with double-valued “charges”, including the masses $\pm m_p$ and $\pm m_e$) and have the limited (macroscopic) radius of action $R_\mu \sim 6 \cdot 10^4$cm.

Consider in this connection again the standard experimental technique used to measure positron/orthopositronium annihilation lifetime spectra.

Figure 2 presents a block diagram of a fast-slow lifetime spectrometer of delayed $\gamma_n$-$\gamma_a$ coincidences.

Recording of real coincidences (in the start-stop arrangement) with a time resolution of $1.7 \cdot 10^{-9}$ s [3] between the signal produced by a nuclear $\gamma_n$-quantum of energy $\simeq 1.28$ MeV (“start”) with the signal generated by the detected $\gamma_a$ annihilation quantum of energy $\simeq (0.34 \div 0.51)$ MeV (“stop”) (corresponding, accordingly, to 3$\gamma$- and 2$\gamma$ annihilation) is accompanied by the energy (amplitude) discrimination in the slow (“side”) coincidence channels (with a resolution $\delta \tau \sim 10^{-6}$ s) between the corresponding signals from the last-but-one dynodes of the lifetime PM tubes, an approach that cuts efficiently random coincidence
noise.

After subtraction of the random coincidence background, the positron annihilation lifetime spectra of inert gases would represent the sums of exponentials with characteristic annihilation rate constants $\lambda_i$

$$N(t) = \sum_{i=0}^{i=2} I_i \cdot e^{-\lambda_i t},$$

where $\lambda_0$ and $I_0$ are, respectively, the rate and intensity of the two-quantum annihilation of the parapositronium component ($p$-$Ps$, $S$-$Ps$), $\lambda_1$ and $I_1$ are the component of two-quantum annihilation of the quasi-free positrons that have not formed positronium (with peculiarity, so-called “shoulder” [5]), and $\lambda_2$, $I_2$ are those of three-quantum annihilation of the orthopositronium component.

It is known that single-quantum $o$-$Ps$ annihilation is forbidden in QED by the momentum conservation law. There is no such limitation in supersymmetric QED (N = 2 SQED) because of total degeneracy of the para- and ortho-superspositronium forming by virtual single-quantum $o$-$Ps$ annihilation into the “mirror Universe” as a result of doubling of the space-time dimension in the final TQT state [5].

Experimental bounds accumulated in the two decades of intense studies of the orthopositronium problem lead one to the conclusion that the additional single-quantum mode of orthopositronium annihilation involves not a photon but rather a notoph ($\gamma^o$ is a zero-mass, zero-helicity particle which is complementary in properties to the photon) [14] and two mirror photons $\gamma'$ with a negative total energy of $3.6 \cdot 10^{-4}$ eV:

$$T_{Ps} \downarrow T_{Ps'} (e^- Ps') \rightarrow \gamma^o \gamma'.$$

This was how the broadening of the framework in which the nature of the $o$-$Ps$ anomalies could be analyzed (from QED to SQED) and the phenomenology of the mechanism of energy and momentum deficit compensation in a single-quantum mode were first formulated [15].

Treated from the SM standpoint, however, detection of a quantum of energy $1.022$ MeV in the “stop” channel of the fast-slow coincidences is forbidden (see the “lower” and “upper” detection thresholds of $\simeq (0.34 \div 0.51)$ MeV, respectively, in Fig. 2).

We are now coming back to the principal question of how the additional realization of supersymmetry would be established in the experiment.

Detection of a single-notoph $o$-$Ps$ annihilation mode should also be accompanied by observation of an energy deficit in the “stop” channel of the lifetime spectrometer: indeed, single-notoph annihilation is identified in the scintillator by the Compton-scattered electron $e$, which is bound in the long-range atom “shell” in a “pair” $e\bar{\tau}$ with the “electronic hole” $\bar{\tau}$ (negative mass) in the “C-field”/“mirror-Universe” structure. Half of the notoph energy, $\simeq 0.51$ MeV, is transferred to the $e$ hole ($\bar{\tau}$) and, thus, “disappears” (“anti-Compton scattering”). As a result, the additional single-notoph mode is detected by the lifetime
spectrometer in the “stop” channel by Compton scattering of an electron \( e \) of energy \( \leq 0.51 \) MeV.

Figure 2: Block-diagram of the lifetime spectrometer (fast-slow \( \gamma_n - \gamma_a \) coincidences). ID – integral discriminator (excludes \( \gamma_a \) detection in the “start” channel); DD – Differential Discriminator (restricts \( \gamma_n \) detection in the ”stop” channel); SCM – Slow Coincidence Module; TAC – Time-to-Amplitude Converter (\( \Delta t \longrightarrow A \)); MPHA – Multichannel Pulse-Height Analyzer.

The experiment [3, 4] is in agreement with the phenomenology proposed for quantitative description of the \( o-Ps \) anomalies provided we assume that the additional single-notoph annihilation mode contributes to the instantaneous coincidence peak [5]. This means that one half of the intensity of the long-lived lifetime spectral component obtained under “resonance conditions” for neon of natural isotope abundance (\( I_2 \)) transfers to the \( t \sim 0 \) region. An electric field of \( \sim 7 \) kV/cm applied parallel to the force of gravity should suppress the additional mode and double the orthopositronium component (\( 2I_2 \)). Accordingly, in the Michigan experiment (non-resonance conditions) an electric field oriented along the force of gravity would bring about complete agreement between \( \lambda_T(\text{exp}) \) with the QED-calculated value \( \lambda_T(\text{theor}) \) [4]; and the disagreement of about \( \Delta \lambda_T/\lambda_T \simeq (0.19 \div 0.14) \% \) found previously (in experiments without electric field) should again appear after the action of the electric field.
has been neutralized (by applying it perpendicular to the force of gravity) [6].

The term “anti-Compton scattering” has been borrowed from Ref. [16]; it appears appropriate to cite here an excerpt from the abstract of this paper written by a classic of the theory of relativity:

”The purpose of this paper is to answer the following question in terms of concepts of classical relativistic mechanics: How is Compton scattering altered if we replace the photon by a particle of zero rest mass and negative energy, and apply the conservation of 4-momentum? <…> Since particles with negative energies are not accepted in modern physics, it is perhaps best to regard this work as a kinematical exercise in Minkowskian geometry, worth recording because the results are not obvious”.

Observation of orthopositronium anomalies gives one physical grounds to broaden the present-day SM. It appears now appropriate to analyze the “anti-Compton scattering” in connection with the detection of notoph in the proposed program of additional measurements, which aim at proving the existence of a connection between the gravity and electromagnetism [5-7].

We may add that the concept of the supersymmetric version of a spin-$\frac{1}{2}$ quasi-particle and hole as supersymmetric partners [17].

Figure 3: Scheme of additional measurements: is there a connection between gravity and electromagnetism? $I_2$ – intensity of the orthopositronium ($^{3}P_0$) lifetime component (with $^{22}$Na as a source of the positrons in a cell filled with gas) for neon of natural isotope abundance (in the “resonance conditions”: $\sim 9\%$ $^{22}$Ne) placed in a dc electric field $\sim 7\ kV/cm$ perpendicular to the force of gravity; $2I_2$ – same in an electric field $\sim 7\ kV/cm$ parallel to the force of gravity (doubling).

To sum up: one should carry out additional measurements, because the result inconceivable in the frame of the SM becomes an expected result in the program of experimentum crucis (Fig. 3).

A positive result of this crucial experiment would mean the birth of new physics that would be complementary to the SM; this physics would restore
also spontaneous violation of the *chiral symmetry*, which would be essential in elucidating the origin not only of the mass of matter [18] but of the *dark matter in the Universe* as well (see [18]) [19].

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