A Proposed Experimentum Crucis for the Orthopositronium Lifetime Anomalies

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Expansion of the Standard Model (SM) for the quantitative description of the orthopositronium lifetime anomalies allows formulation of additional experimental tests of supersymmetry in the final state of the positron beta-decay of nuclei such as ^{22}Na, ^{68}Ga, and resolution of the results of the last Michigan experiment (2003).

In 2003, at the University of Michigan (Ann Arbor), a measurement of the o-Ps annihilation rate was carried out, and the researchers reported complete agreement between the experimental value, $\lambda_{\text{T}} = 7.0404(10)(8)\,\mu\text{s}^{-1}$, and the value calculated in the frame of QED, $\lambda_{\text{T(theor)}} = 7.039979(11)\mu\text{s}^{-1}$ [1]. These measurements were performed by a different technique, namely, a dc electric field of 7 kV/cm was introduced into the measurement cell. For this reason, and since they disregarded the "isotope anomaly" of o-Ps in gaseous neon in "resonance conditions" [2, 3], authors [1] could not include the *additional* action of the electric field on the observed o-Ps self-annihilation rate $\lambda_{\text{T(exp)}}$ [3], notwithstanding 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 $\Delta\lambda_{\text{T}} \simeq 0.19 \div 0.14\%$ over the calculated value $\lambda_{\text{T(theor)}}$, which had been reported earlier by the Michigan group and referred to quantitatively as the *macroscopic quantum effect* (the "λ_{T}-anomaly" [3])*.

This is why rejection [1] of the conclusions drawn from the earlier high-precision λ_{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* of the parameter V 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 opens up such a possibility; indeed, restoration of the symmetry under discussion "should be accompanied by doubling of the space-time dimension" [4].

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

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*Here and so forth the sign $\div$ means that the values were obtained in the gas and vacuum experiments respectively.
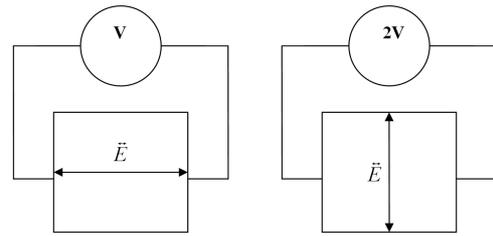

Fig. 1: Scheme and the *result* of a Gedanken experiment with an electric field in a laboratory on Earth. The measuring cell is filled with gas. $\vec{E}$ is orientation and dc voltage of an electric field; V is the value of the parameter to be measured.

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 $\gamma_{\text{n}}-\gamma_{\text{a}}$ coincidences.

Recording of *real* coincidences (in the start-stop arrangement) with a time resolution of 1.7×10^{-9} s [2] between the signal produced by a nuclear γ_{n} quantum of energy $\simeq 1.28$ MeV ("start") with the signal generated by the detected γ_{a} annihilation quantum of energy $\simeq 0.34 \div 0.51$ MeV ("stop", corresponding, accordingly, to 3γ and 2γ-annihilation) is accompanied by the energy (amplitude) discrimination in the slow ("side") coincidence channels (with a resolution $\delta\tau_{\text{s}} \sim 10^{-6}$ 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 λ_i

$$N(t) = \sum_{i=0}^{i=2} \text{I}_i\, e^{-\lambda_i t},$$

where λ_0 and I_0 are, respectively, the rate and intensity of *two-quantum* annihilation of the para-positronium component (p-Ps), λ_1 and I_1 are the components of *two-quantum* annihilation of the quasi-free positrons that have not formed positronium (with so-called "shoulder" peculiarity [5]), and
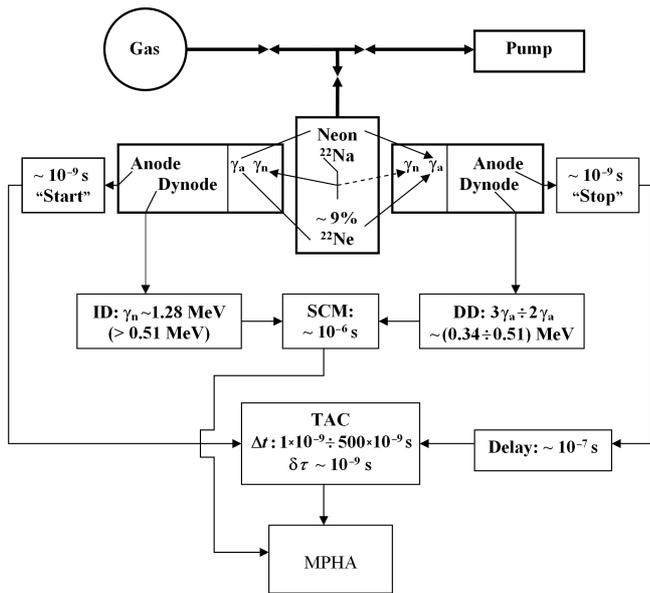
Fig. 2: Block-diagram of the lifetime spectrometer (fast-slow γ_n–γ_a coincidences). ID is for Integral Discriminator (excludes γ_a detection in the "start" channel); DD is for Differential Discriminator (restricts γ_n detection in the "stop" channel); SCM is for Slow Coincidence Module; TAC is for Time-to-Amplitude Converter ($\Delta t \to$ amplitude); MPHA is multichannel pulse-height analyzer.

λ_2 and I_2 are those of *three-quantum annihilation* of the orthopositronium component.

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* (γ° is a zero-mass, zero-helicity particle which is complementary in properties to the photon) [7] and two *mirror photons* γ' with a negative total energy of 3.6×10^{-4} eV [3, 5]:

$$\text{o-Ps} \backslash \text{p-Ps}' \,(\text{p-Ps}') \longrightarrow \gamma^\circ \backslash 2\gamma'.$$
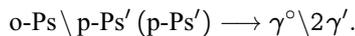
This was how the broadening of the framework in which the nature of the o-Ps anomalies could be analyzed (from QED to SQED) and the phenomenology of the mechanism of energy and momentum deficit compensation in a single-quantum mode were first formulated [7].

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 $\sim 0.34 \div 0.51$ MeV, respectively, in Fig. 2).

We now come 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
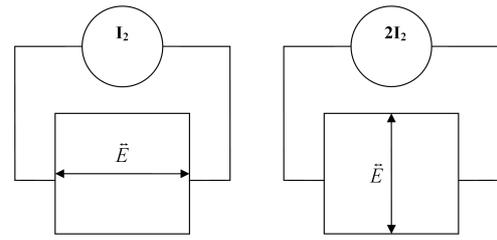

Fig. 3: Scheme of additional measurements: is there a connection between gravity and electromagnetism?

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$\bar{\text{e}}$ with the "electronic hole" $\bar{\text{e}}$ (negative mass) in the "C-field/mirror Universe" structure. Half of the notoph energy, ~ 0.51 MeV, is transferred to the e hole ($\bar{\text{e}}$) 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 $\leqslant 0.51$ eV.

The experiment 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 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 $\lambda_{T(exp)}$ with the QED-calculated value $\lambda_{T(theor)}$; 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) [3].

The term "anti-Compton scattering" has been borrowed from J. L. Synge [8]; it appears appropriate to cite here an excerpt from the abstract of this paper written by a celebrated proponent 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 now appears appropriate to analyze "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 gravity and electromagnetism [3].

We may add that the concept of the supersymmetric version of a *spin-$\frac{1}{2}$ quasi-particle* and a hole as *supersymmetric partners* has been discussed in the literature [9].

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 Standard Model.

References

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