The Origin of the Measured Proton-Electromagnetic-Structure Anomaly

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Abstract: Theoretical results obtained in this paper are perfectly consistent with the Jefferson Lab experimental data presented by R. Li, et al. (2022). Here we have linked the definitions of electric and magnetic polarizabilities to the internal structure of the proton described in the Scale-Symmetric Theory (SST). We then showed that we should observe a local enhancement of the polarizabilities (an anomaly) for the squared four-momentum transfer from 0.31 up to 0.42 squared giga-electron volts – it follows from the internal dynamics of the proton. We calculated also the proton polarizability radii and the maximum polarizability for the anomalous region.

1. The SST definitions of the electric and magnetic generalized polarizabilities and the proton polarizability radii

Electric and magnetic polarizabilities determine the dynamical response of a bound system to external fields. In such a way we can decode the proton structure. There is an anomaly to the behaviour of the proton's electric generalized polarizability so it suggests a new dynamical mechanism in the proton that does not appear in the mainstream nuclear theory. Moreover, the measured mean square electric polarizability radius is much larger than the mean square charge radius of the proton.

The electric polarizability, α_E, in isotropic media is defined as the ratio of the induced dipole moment $p = q\ r$ (where r is the distance between electric charges q) to the electric field E

$$\alpha_E = q\ r / E\ . \qquad (1)$$

In the Lorentz-force formula, a force, F, in the direction of the electric field E, is proportional to the magnitude of the field and the quantity of charge Q^*

$$F = Q^*\ E\ . \qquad (2)$$

The Coulomb force in CGS system, F_{CGS}, is defined as follows

$$F_{CGS} = q\ Q^* / r^2\ , \qquad (3)$$

whereas the quantum force from exchanges of masses/energies is defined as follows

$$F_{CGS} = G_{CGS} M_{source,i} m_{carrier,i} / r^2 . \qquad (4)$$

From formulae (1)-(4) we have

$$\alpha_{E,CGS} = [M_{source,1} m_{carrier,1} / (M_{source,2} m_{carrier,2})] r^3 . \qquad (5)$$

The external electric field (it is in the denominator) produces the virtual particle-antiparticle pairs so we can assume that there is satisfied following formula

$$M_{source,2} m_{carrier,2} = \Sigma_i Q_i^2 = Q^2 + Q_{internal}^2 , \qquad (6)$$

where Q^2 is the four-momentum transfer squared, while $Q_{internal}^2$ defines the internal four-momentum transfer squared in the proton caused by the virtual field composed of the $W_{(+),d=4}W_{(-),d=4}$ pairs, where $W_{(+-),d=4}$ = 0.16201257 **GeV** are the virtual relativistic bosons [1]. It leads to following invariant value

$$Q_{internal}^2 = (2 W_{(+-),d=4})^2 = 0.104992 \textbf{ GeV}^2 . \qquad (7)$$

Emphasize that we already used the virtual field composed of the $W_{(+),d=4}W_{(-),d=4}$ pairs to explain the frequency of the hydrogen spin-flip transition (see Section A3 in [1]). Range is inversely proportional to mass of particle so we should take into account the lightest electrically charged boson – from Table 2 in [1] follows that it is the boson $W_{(+-),d=4} \approx$ 162.01257 **MeV**.

According to SST, there are two states of the proton: $H^+W_{(o),d=1}$ and $H^oW_{(+),d=1}$, where H^+ = 0.72743922 **GeV** and H^o denote the core of baryons and their masses [1]. We see that the mean distance between the charged centre of the core of proton and the charged $W_{(+),d=1}$ boson is $R_{d=1} = A + B \approx 1.19928$ **fm** [1] and it is the SST proton electric polarizability radius $r = R_{d=1} = r_{\alpha(E)} = A + B$ in formula (5). We obtain the following SST value for the squared electric polarizability radius (the virtual photons are scattered on H^+ and $W_{(+),d=1}$)

$$\langle r_{\alpha(E)}^2 \rangle_{SST} = (A + B)^2 = 1.438 \textbf{ fm}^2 . \qquad (8)$$

We can compare this value with the experimental data [2]

$$\langle r_{\alpha(E)}^2 \rangle_{Exp} = 1.36(29) \textbf{ fm}^2 . \qquad (9)$$

We see that our theoretical result is consistent with experimental data.

Emphasize that initially the electric virtual field is a disc in the plane of the equator of the core of baryons with a radius equal to A + B. But the surface tension on the surface of such virtual field causes this field to have spherical symmetry with a radius of the electric sphere equal to A + B.

The virtual weak mass of the charged core of the proton is $\alpha_{w(p)}H^+$, where $\alpha_{w(p)} \approx$ 0.0187229 is the coupling constant for the nuclear weak interactions [1]. On the other hand, the virtual electromagnetic mass of the core is $\alpha_{em}H^+$, where α_{em} is the fine structure constant [1]. Since $\alpha_{w(p)}H^{+} > \alpha_{em}H^{+}$ so the electromagnetic mass can be emitted and absorbed by the weak mass, so we assume that in (5) we have

$$M_{source,1} = \alpha_{w(p)}H^{+}\,, \tag{10}$$

$$M_{carrier,1} = \alpha_{em}H^{+}\,, \tag{11}$$

The above remarks lead to our definition of the electric generalized polarizability

$$\alpha_{E,SST}(Q^2) = \{\alpha_{w(p)}\alpha_{em}H^{+2} / (Q^2 + 0.104992)\}\,(A + B)^3\,. \tag{12}$$

For $Q^2 = 0$ we obtain $\alpha_{E,CGS}(Q^2 = 0) = 11.88\cdot10^{-4}$ **fm³** (the experimental result is $11.2(4)\cdot10^{-4}$ **fm³** [3]).
For $Q^2 = 0.31$ **GeV²** we obtain $\alpha_{E,CGS}(Q^2 = 0.31) = 3.00\cdot10^{-4}$ **fm³**.
For $Q^2 = 1$ **GeV²** we obtain $\alpha_{E,CGS}(Q^2 = 1) = 1.13\cdot10^{-4}$ **fm³**.

The SST proton magnetic polarizability radius, $r_{\beta(M)}$, is the equatorial radius of the spinning torus/electric-charge in the core of the proton, $r_{\beta(M)} = A = 0.6974425$ **fm** [1], (it also, due to the surface tension of the virtual magnetic field, has spherical symmetry), i.e. we have

$$<r_{\beta(M)}{}^2>_{SST} = A^2 = 0.4864\ \mathbf{fm^2}\,. \tag{13}$$

We can compare this value with the experimental data [2]

$$<r_{\beta(M)}{}^2>_{Exp} = 0.63(31)\ \mathbf{fm^2}\,. \tag{14}$$

We see that our theoretical result is consistent with experimental data.
From (5), (12) and (13) we obtain our definition of the magnetic generalized polarizability

$$\beta_{M,SST}(Q^2) = \alpha_{E,SST}(Q^2)\,[A / (A + B)]^3\,. \tag{15}$$

The factor of proportionality of the electric and magnetic polarizabilities is

$$f = \alpha_{E,SST}(Q^2) / \beta_{M,SST}(Q^2) = [(A + B) / A]^3 = 5.084\,. \tag{16}$$

For $Q^2 = 0$ we obtain $\beta_{M,CGS}(Q^2 = 0) = 2.34\cdot10^{-4}$ **fm³** (the experimental result is $2.5(4)\cdot10^{-4}$ **fm³** [3]).
For $Q^2 = 0.31$ **GeV²** we obtain $\beta_{M,CGS}(Q^2 = 0.31) = 0.59\cdot10^{-4}$ **fm³**.
For $Q^2 = 1$ **GeV²** we obtain $\beta_{M,CGS}(Q^2 = 1) = 0.22\cdot10^{-4}$ **fm³**.

2. The proton-electromagnetic-structure anomaly

The SST dynamics of the proton leads to the local enhancement of the electric and magnetic polarizabilities (an anomaly). The SST structure of the proton shows that the virtual field in the proton is composed of the virtual $W_{(+),d=4}W_{(-),d=4}$ dipoles [1]. Due to the lowest relativistic mass of such charged bosons, such field is the ground state of the proton virtual field. Due to the four-particle symmetry, such virtual dipoles are created as the pairs of dipoles. Such virtual fields, due to the surface tension, have spherical symmetry. As the response of such a system to an external electromagnetic field (in [2] it is the virtual Compton scattering (VCS)) density of the virtual dipoles in the virtual fields increases. When the four-momentum transfer Q is equal to mass of four charged pions, i.e. $Q = 4\pi^{\pm} = 0.5583$ **GeV** (i.e. $Q^2 = (4\pi^{\pm})^2 = 0.3117$ **GeV²**), then in the virtual fields dominate the virtual $\pi^+\pi^-$ dipoles (they are created as the $\pi^+\pi^-\pi^+\pi^-$ quadrupoles) because their absolute mass is lower than mass of the relativistic $W_{(+),d=4}W_{(-),d=4}$ dipoles. For $Q^2 > 0.3117$ **GeV²**, with increasing Q^2, density of the virtual $\pi^+\pi^-$ dipoles decreases and for $Q = 4W_{(+-),d=4} = 0.6480$ **GeV** (i.e. $Q^2 = (4W_{(+-),d=4})^2 = 0.4200$ **GeV²**) the system returns to the "normal state". We see that the anomalous region has the lower and upper limits:

$$0.3117 \text{ GeV}^2 \le Q^2_{anomalous} \le 0.4200 \text{ GeV}^2 . \qquad (17)$$

The virtual $\pi^+\pi^-$ pairs can interact with the charged core H^+. It increases the electric and magnetic polarizabilities. The factor of proportionality is

$$F = [(H^+ + 2\,\pi^{\pm}) / H^+]^2 = 1.9147 . \qquad (18)$$

The maximum anomalous polarizabilities are for $Q^2 = 0.31$ **GeV²** and are as follows.

$\alpha_{E,CGS}(Q^2 = 0.31)_{anomalous} = F \cdot 3.00\cdot10^{-4}$ **fm³** $= 5.74\cdot10^{-4}$ **fm³**.

$\beta_{M,CGS}(Q^2 = 0.31)_{anomalous} = F \cdot 0.59\cdot10^{-4}$ **fm³** $= 1.13\cdot10^{-4}$ **fm³**.

The SST results are collected in Fig.1.

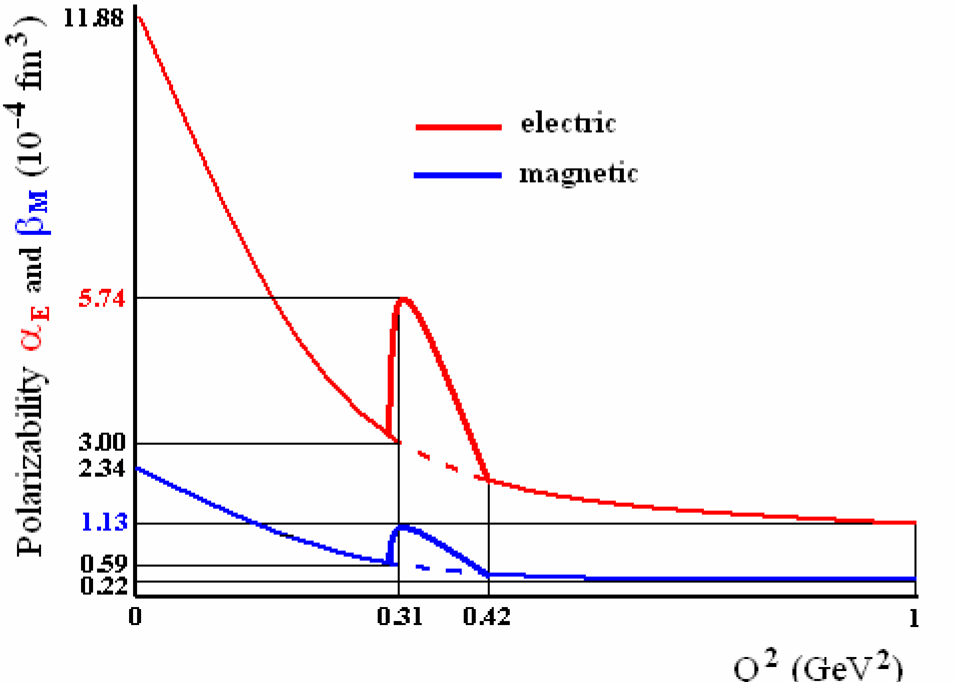

Fig.1
Dependence of the electric and magnetic polarizabilities on the squared four-momentum transfer for the proton.

3. Summary

Here we showed that the anomaly in the electromagnetic structure of the proton concerns both the electric and magnetic structures but the maximum enhancement of the magnetic polarizability is only $0.54 \cdot 10^{-4}$ **fm^3** in comparison with the $2.74 \cdot 10^{-4}$ **fm^3** for the electric polarizability – it causes that it is very difficult to detect the magnetic anomaly. Just we need more precise experiments.

Our perfect results, impossible to achieve with the mainstream theory, suggest that the Scale-Symmetric Theory is indeed the lacking part of the Theory of Everything.

References

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