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Review Article

On a Non-Standard Atomic Model Developed in the Context of Bridge Electromagnetic Theory

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APPENDIX-A

The calculus of the orbital sommerfeld constant α_n

Let us consider an observer placed on a point P of an ideal expanding spherical surface $\sum(t)$ inside which a dipole with fixed polarization in space and dipole moment $\mathbf{d}=e\mathbf{R}$ is placed. The energy per unit time pertaining to an infinitesimal portion of the expanding surface is equal to the flux of the Poynting vector $\mathbf{S}$ of the source through the infinitesimal surface $d\mathbf{a}$. The total energy observed in P during the time interval τ is given by:

$$\delta d\varepsilon = \int_0^{\tau} \mathbf{S}_r \cdot d\mathbf{a}\, dt \tag{A.1}$$

where the radial component of the Poynting vector $\boldsymbol{S}_r$ in equation (3) is parallel to direction of the surface element. Such an observer sees the emission of the source just along the direction characterised by the angles (θ, φ), but by isotropy it assumes that the source emits in all other directions as it does in the direction in which it observes the source, that is, that the DEMS has a spherical symmetry as in a point-like dipole where $\boldsymbol{S} \equiv \boldsymbol{S}_r$ are identical and rewrites the equation (A.1) as

$$\delta d\varepsilon = \int_0^{\tau} S\, da\, dt \tag{A.2}$$

By equation (A.2), the total energy observed in P during the time interval τ is

$$\delta\varepsilon = \int_0^{\tau} \left(\iint_{\sum(t)} S\, da \right) dt = \frac{1}{c} \int_{V_{\delta\sum}} S\, d^3x \tag{A.3}$$

Where S/c is the energy density contribute inside the spherical crown of volume $V_{\delta\sum}$ associated with the energy emitted along the direction of P in the time τ. Each observer in space obtains the total energy emitted by the DEMS by integrating over all the energies measured by the observers placed in each point P of the surface $\sum(t)$

$$E_{rad} = \int_{P_{\sum}} \delta\varepsilon = \int_0^{2\pi} \int_0^{\pi} \left(\frac{1}{c} \int_{V_{\delta\sum}} S\, d^3x \right) d\theta d\varphi \tag{A.4}$$

The same result is obtained in the case of time dependent variable polarization in which during the arbitrary time τ, each observer sees the dipole moment to change length and direction with the effect of to vary the energy emitted per unit time along the direction of observation. During the same time, all observers statistically measure the same average amount of energy. Assuming that during the arbitrary time interval τ, the energy produced is emitted in such a way that the energy emitted per unit time by a DEMS with time dependent polarization across an infinitesimal portion of surface equals the mean energy emitted by a DEMS with fixed polarization, we write the total energy produced for both types of sources as:

$$E = \int_0^{2\pi} \int_0^{\pi} \left(\frac{1}{c} \int_{V_{\delta\sum}} \bar{S}\, d^3x \right) d\theta d\varphi \tag{A.5}$$

Considering the evolution in space-time of the two charges during their interaction under the action of the mutual direct and undirect electromagnetic force, because of the delay effect in the signal propagation due to the finite speed of light, the charges at time t are subject to the source field produced at a previous time t' when the dipole moment of the source was $\mathbf{d}' = e\mathbf{R}'$. In other words, the source feels the past state of the electromagnetic field and it can be assumed that the interaction occurs as if the source field were rotated from an average angle of incidence or diffusion, producing a torsion in the electromagnetic field of the source that is not deterministically predictable, so the Poynting vector $\simeq$ describes the emission of the source as a stochastic process.

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From the geometry of the process, the values of the angles of incidence and diffusion are always within the angular interval [0, π/2], the non-point-like spatial distribution of the incident charge *e* determines an angular spread of charge image in the region in which the retarded field begins to act so the angular zone in which the charge is spread extends for just a few seconds of arc. Therefore, in accordance with [4,6] the interactions that contribute to the source zone of DEMS occur in agreement with BT at a distance in the range [λ, 3λ/2] of the dipole length, with a mean angle of incidence $\bar{\theta} = \pi/4 + \phi$, only a bit greater than the mean interaction angle π/4 used in the model [5].

Following Auci [5,6], considering the force between a pair of charges, the dipole in its actual position is subject to a Lorentz's force **F** produced by the electromagnetic field of the source in its effective position. Since $|\boldsymbol{\mathcal{E}}| = |\mathbf{B}|$, the Lorentz's force acting on the moving charge along the direction of the dipole axis $\hat{\mathbf{R}}$ makes a work

$$W = \mathbf{F} \cdot \mathbf{R} = e|\boldsymbol{\mathcal{E}}||\mathbf{R}|\left(\hat{\boldsymbol{\varepsilon}} \cdot \hat{\mathbf{R}} + \beta\right) \tag{A.6}$$

on the dipole, varying its strength. The intensity of the Poynting vector associated to the electromagnetic field of the induction zone of the dipole is

$$S = \frac{c}{4\pi}|\boldsymbol{\mathcal{E}}|^2 = \frac{c}{4\pi}\frac{e^2}{r^4}|\boldsymbol{\Theta}| \tag{A.7}$$

Assuming an observer on the first wavefront, its position is at the beginning of the radiation zone of the DEMS that is, at a distance *r*=λ by the ideal centre of the source. Using the equation (A.7) the mean square value of the electromagnetic strength acting during the collision on the dipole moment is

$$\left\langle F^2 \right\rangle = \frac{\int_{\lambda}^{3\lambda/2} \left(\mathbf{F} \cdot \hat{\mathbf{R}}\right)^2 d\mathrm{R}}{\int_{\lambda}^{3\lambda/2} d\mathrm{R}} = \frac{4\pi}{c} e^2 \left(\hat{\boldsymbol{\varepsilon}} \cdot \hat{\mathbf{R}} + \beta\right) \frac{\int_{\lambda}^{3\lambda/2} S \, d\mathrm{R}}{\int_{\lambda}^{3\lambda/2} d\mathrm{R}} \tag{A.8}$$

and the mean square value of the work made by the electromagnetic field on the moving charges is

$$\left\langle W^2 \right\rangle = \frac{\int_{\lambda}^{3\lambda/2} \left(\mathbf{F} \cdot \mathbf{R}\right)^2 d\mathrm{R}}{\int_{\lambda}^{3\lambda/2} d\mathrm{R}} = \frac{4\pi}{c} e^2 \left(\hat{\boldsymbol{\varepsilon}} \cdot \hat{\mathbf{R}} + \beta\right) \frac{\int_{\lambda}^{3\lambda/2} S \, \mathrm{R}^2 d\mathrm{R}}{\int_{\lambda}^{3\lambda/2} d\mathrm{R}} \tag{A.9}$$

from which, considering the electromagnetic interaction as a stochastic process, because is not possible to know the exact distance and angular position of the two approaching particles, the ratio between the equation (A.9) and equation (A.8), by correcting the mean angle of incidence with an opportune angle of torsion as $\bar{\theta} = \pi/4 + \phi$ which value of ϕ is now still to estimate, the probability density characterising the squared of the interaction distance of the two interacting particles obtained by means of the electromagnetic structure function of the electromagnetic field of the DEMS is

$$\Pi(\rho, \phi) = \frac{\Theta(\rho, \phi)}{\int_{1}^{3/2} \Theta(\rho, \phi) d\rho} \tag{A.10}$$

giving for the mean square distance of interaction

$$\left\langle R^2 \right\rangle = \frac{\left\langle W^2 \right\rangle}{\left\langle F^2 \right\rangle} = \lambda^2 \int_{1}^{3/2} \Pi(\rho, \phi) \rho^2 d\rho \tag{A.11}$$

that allows to define the root mean squared of the normalised dipole length that characterizes the DEMS at any wavelength λ of the DEMS

$$\bar{\rho}_{\phi} = \frac{\sqrt{\left\langle R^2 \right\rangle}}{\lambda} = \sqrt{\int_{1}^{3/2} \Pi(\rho, \phi) \rho^2 d\rho} \tag{A.12}$$

The root mean squared length (A.12) represents the characteristic direct distance parameter between the interacting charges during the building up of the source zone; hence equation (A.12) defines the dipole length characterising the stochastic free interaction between the two charges.

Equation (A.12) with ϕ =0 gives $\bar{\rho}_0 = 1.27555787491640$ that used in the expression in round bracket of the equation (4) gives the value of the electromagnetic structure constant corresponding to first approximation of the inverse fine structure constant σ_0 =137.036669830443.

Considering the wave description (51b) of the captured electron, is possible to measure the angular extension of the electron seen from the point of view of the proton. Assuming as angle the generalised phase $\varphi = \pm\frac{P}{\hbar}x$ at time *t*=0, the equation (51b) it reduced to

$$\psi = e^{\pm i\varphi} \tag{A.13}$$

occupying a phase position defined in space-time by

$$\mathrm{Re}(\psi) = \cos\varphi \tag{A.14}$$

with a mean squared root

$$\bar{\varphi} = \sqrt{\frac{\int_{-\pi/2}^{\pi/2} \varphi^2 \,\mathrm{Re}(\psi)d\varphi}{\int_{-\pi/2}^{\pi/2} \mathrm{Re}(\psi)d\varphi}} = \pm\, 0.6836673901 \tag{A.15}$$

corresponding to the amplitude of the phase interval of the electron: $\Delta\varphi = 2\bar{\varphi}$, associated to the space interval $\Delta x_{el} = \frac{\Delta\varphi}{2\pi}\lambda_{el}$ with $\frac{\Delta\varphi}{2\pi} = 0.2176180891$.

To estimate the curved spatial interval D_{el} in which the electron can be considered spread along its pseudo-orbit during the electron capture process, one considers that $\frac{D_{el}}{2r_{el}} = \frac{\Delta x_{el}}{\lambda_{el}} = \frac{\Delta\varphi}{2\pi}$, it follows

$$D_{el} = \frac{\Delta x_{el}}{\lambda_{el}} 2r_{el} = 0.4352361782 r_{el} \tag{A.16}$$

defined the effective mean orbital diameter of the electron, that is, the footprint of the electron on the orbit. For the electron of the atom of hydrogen on the fundamental pseudo-orbit, that is, (Z=1, n=1), $r_{el} = \alpha_1 \lambda\!\!\!^{-}_{el}$ is the classic radius of the electron. In general, by using the orbital electron speed equation (36) for an electron captured by a nucleus with Z protons orbiting on the *n*-th pseudo-orbit, the corresponding value of the classic radius of the electron is $r_{el} = \beta_n \lambda\!\!\!^{-}_{el}$. Applying the relativistic transformation of the de Broglie wavelength of the electron $\lambda_{el} = \lambda_n \beta_n \gamma_n$ the deBroglie wavelength of the electron on the *n*-th pseudo-orbit is written as

$$\lambda\!\!\!^{-}_n = r_{el}\beta_n^{-2}\sqrt{1-\beta_n^2} \tag{A.17}$$

with $\beta_n = Z\alpha_n/n$. It follows that the measure of the arc of trajectory D_{el} corresponding to the angular footprint of the electron on its *n*-th orbit in terms of de Broglie wavelength λ_n of the electron is given by $D_{el} = \phi\lambda\!\!\!^{-}_n$, by using the equation (A.16) and equation (A.17), the angular footprint of the captured electron on its orbit is

$$\phi = \frac{D_{el}}{\lambda\!\!\!^{-}_n} = 0.4352361782 \frac{\beta_n^2}{\sqrt{1-\beta_n^2}} \tag{A.18}$$

which corresponds to the angular diameter of the electron on the *n*-th pseudo-orbit seen by nucleus, that is, to the correction to apply at the mean angle of interaction $\bar{\theta}$ to consider the delay effect in the interaction.

Considering the first rough value of the alpha constant $\alpha^{(0)}$ obtained by using the ratio $\bar{\rho}_0$ calculated with equation (A.12) without to apply corrections, in Table A.1 are shown the results at the zero level of angular correction of the electromagnetic structure constant and of the fine structure constant.

Table A.1: Value of the constants of electromagnetic and fine structure without angular correction and value of the first level of correction obtained.

Estimation at zero level of angular correction ϕ =0	**Value**
Electromagnetic structure constant	$\sigma^{(0)}$ =137.036669830443
Alpha constant	$\alpha^{(0)}$ =**7.29731**685130200 **10**$^{-3}$
First level of angular correction	$\phi^{(1)}$ =2.31773062645502 10^{-5} *rad*

The evidence that the correction at the average angle of interaction introduced for the presence of a non-point footprint of the electron on its trajectory improves the theoretical calculation of the electromagnetic structure constant characterizing the orbital velocity of the electron itself, essential to define in turn the magnitude of angular correction, allows to define a recursive algorithmic method [10] that converges to a stable final value with a desired precision of the fine structure constant which, for this reason, could represent the absolute theoretical value of the atomic value of the Sommerfeld constant for an atom with Z protons and an electron on the *n*-th energetic level. The recursive method presented is described step by step in Table A.2. Convergence at a stable value of the fifteen-digit fine structure constant is achieved quickly within 4-5 cycles. The obtained value of the electromagnetic structure constant is subject only to the limit of the theoretical model adopted.

Table A.2: Recursive sequence for the calculus of the electromagnetic structure constant on the *n*-th level.

Step 1	With ϕ =0 calculate the value of $\sigma_n^{(0)}, \alpha_n^{(0)} = \left(\sigma_n^{(0)}\right)^{-1}$ $\bar{\rho}_0 = \sqrt{\int_1^{3/2} \Pi(\rho,0)\rho^2 d\rho} \rightarrow \sigma_n^{(0)} = \frac{4\pi}{3}\int_0^{\pi} \Theta_t(\bar{\rho}_0,\theta)d\theta + \frac{1}{4\pi\bar{\rho}_0^2}$
First angular correction	Using $\alpha_n^{(0)}$ calculate the next angular correction ϕ_1 $\phi_1 = 0.4352361782\left(\beta_n^{(0)}\right)^2 \gamma_n^{(0)}$
Step 2	With ϕ_1 the value calculate the value $\sigma_n^{(0)}, \alpha_n^{(1)} = \left(\sigma_n^{(1)}\right)^{-1}$ $\bar{\rho}_{\phi_1} = \sqrt{\int_1^{3/2} \Pi(\rho,\phi_1)\rho^2 d\rho} \qquad \sigma_n^{(1)} = \frac{4\pi}{3}\int_0^{\pi} \Theta_t(\bar{\rho}_1,\theta)d\theta + \frac{1}{4\pi\bar{\rho}_1^2}$

Second angular correction	Using $\alpha_n^{(1)}$ calculate the next angular correction ϕ_2 $\phi_2 = 0.4352361782\ \left(\beta_n^{(1)}\right)^2 \gamma_n^{(1)}$
...	...
Step *n*	With the value ϕ_{n-1} calculate the value $\sigma_n^{(n-1)}, \alpha_n^{(n-1)} = \left(\sigma_n^{(n-1)}\right)^{-1}$ $\bar{\rho}_{\phi_{n-1}} = \sqrt{\int_1^{3/2} \Pi(\rho, \phi_{n-1}) \rho^2 d\rho}$ $\quad \sigma_n^{(n-1)} = \frac{4\pi}{3} \int_0^{\pi} \Theta_t(\bar{\rho}_{n-1}, \theta) d\theta + \frac{1}{4\pi \bar{\rho}_{n-1}^2}$
Last angular correction	Using $\alpha_n^{(n-1)}$ calculate the next angular correction ϕ_n $\phi_n = 0.4352361782 \left(\beta_n^{(n-1)}\right)^2 \gamma_n^{(n-1)}$
Step *n* +1	With the value ϕ_n calculate the final stable value of $\sigma_n, \alpha_n = \sigma_n^{-1}$ $\rho^* = \sqrt{\int_1^{3/2} \Pi(\rho, \phi_n) \rho^2 d\rho} \rightarrow \sigma_n = \frac{4\pi}{3} \int_0^{\pi} \Theta_t(\rho^*, \theta) d\theta + \frac{1}{4\pi \rho^{*2}}$

Note: In order are used the equation (A.10), (A.12) the expression of σ and the equation (A.18).

The recursive sequence is divided into two sequential phases. In the first is estimated the mean square root of the length of the forming dipole and its value calculates the value of the fine structure constant associated with the electron capture process. In the second phase, the estimated fine structure constant is used to obtain the first angular correction necessary for the presence of the electron footprint in orbit. The sequence if concatenated can be repeated an arbitrary number of times, each repetition can be interpreted as a process that pushes the electron towards a state of equilibrium in the atom. The fine structure constant in the step *n*+1 in Table A.2 is that associated with an atom with Z protons at *n*-th energy level.