

Interpretation of FSC-Experiments Deviation

manfred geilhaupt (✉ manfred.geilhaupt@hsnr.de)

Research Article

Keywords: Fine Structure Constant, Atomic Interferometry

Posted Date: June 2nd, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-579464/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Interpretation of FSC-Experiments Deviation

Manfred Geilhaupt*

Germany

ABSTRACT

The Fine Structure Constant (FSC) discussion started 1916 with the definition of alpha by Sommerfeld ($\alpha=e^2/(2\cdot h \cdot c \cdot \epsilon_0)$) which must be a constant number in so far as the elementary charge (e) is a constant. Morel et al. (2020) and Parker et al. (2018) presented the most accurate FSC from similar atomic (Rb and Cs) interferometric experiments recently. Surprisingly there is a „tension“ between their two values from an experimental point of view manifesting a theoretical problem due to a „running“ alpha-number indicating a „running“ elementary charge-value which should not be the case in Standard Physics. Here is our interpretation from the General Relativity (GR) point of view to come up with a constant alpha(0) within both experiments.

Morel (Rb: $1/\alpha_{Rb} = 137,035999206(11)$) and Parker (Cs: $1/\alpha_{Cs} = 137,035999046(27)$)

I. Introduction

„The Standard-Model (SM) reveals that the Fine-Structure-Constant (FSC) characterises the strength of the electromagnetic interaction between elementary charged particles and therefore is ubiquitous in physics.“ [1]

„The greatest triumphs of Quantum Electrodynamics (QED) is revealing the magnetic moment of the electron depending on alpha. The magnetic moment of an electron is subtly larger than that expected for a charged, point-like particle by a factor (a_e) of roughly $a_e(\alpha) = 1 + \alpha/(2\pi)$.“ [1].

The corresponding magnetic moment „($g_e(m_\mu) - 2$) anomaly“ of the magnetic moment (m_μ) has been verified to ever-increasing accuracy by „infinite“ number of Feynman-Integrals calculation. Nevertheless there is a 2.5σ deviation between measurements of $a_e(m_\mu) = (g_e(m_\mu) - 2)/2$ from experiment and the Standard Model prediction of $a_e(\alpha)$ using various statistical methods from theory. [1,2]

„Atom interferometers measure α is based on measuring the recoil kinetic energy transferred. First, a laser beam makes an atom absorb and emit multiple photons and, in doing so, recoil. The mass of the atom $m(A)$ is deduced by measuring the kinetic energy of this recoil. After measuring k , the photon wavenumber, this recoil kinetic energy is given by ω_r , where $\omega_r = h \cdot k / (4\pi \cdot m(A))$ is the recoil frequency of the Atom.“ [1]

The Atom to electron mass ratio ($m(A)/m_{eE}(A)$) is known to accuracy better than 0.1 ppb for many species [3]. Second, the electron's mass $m_{eE}(A)$ is calculated using the precisely known ratio of the atom's mass $m(A)$ to the mass of an electron $m_{eE}(A)$ from experiment (Morel and Parker). At least, α is determined from the data: electron's mass $m_{eE}(A)$, atom mass $m(A)$, and the binding energy $E_B(R_y)$ of a hydrogen atom due to $R_y(m_{eCodata})$ (Rydberg constant), which is known from spectroscopy representing also the H-ionisation energy.[3]

Here is the formula used to calculate $\alpha(A)$ [4]

$$1 \quad \alpha^2 = 2 * (Ry/c) * (m(A)/m_e(A)) * (h/m(A))$$

$R_y (=R_\infty$ proportional to $m_e \cdot e^4$) the Rydberg-Constant (in units 1/m) from Codata [4]

$$2 \quad R_\infty = \frac{\alpha^2}{2} \frac{1}{\lambda_{C,e}} = \frac{\alpha^2}{2} \frac{m_e c}{h} = \frac{m_e e^4}{8c\epsilon_0^2 h^3}$$

R_y , direct measurement from spectroscopy with high accuracy, theoretically depends on the (SR-invariant) electron restmass m_e from Codata (formula 2). BUT this restmass m_e must be different to mass $m_{eE}(A)$ of the electron released in the process due to the „recoil velocity“. Otherwise we can not explain a constant $\alpha(0)$ value. So we have to give up the „SR-invariant m_e “ if the SR relativistic effect does not make such a significant difference between the relativistic mass $m_{eE}(v,A)$ and its restmass $m_{eE}(A)$ at zero velocity because of a tiny recoil velocity estimated and therefore not discussed within the two papers. So $m_{eE}(Cs)$ must be measured significantly different from $m_{eE}(Rb)$ to come up with a constant $\alpha(0)$ value measured within both experiments. (This fact is not discussed in both papers.)

Morel *et al.* have improved the accuracy of α to 81 p.p.t. [3] Although there is only a smaller tension between each of the determinations of α (Rb) (1/137.035999206(11)) and α (Cs) (137.035999046(27)) to the standard-model prediction of α (g_s) (1/137.035999174 (35)), from the anomalous magnetic moment [3,4], there is a strong tension between Morel [3] (Rb:137.035999206(11)) and Parker [4] (Cs: 137.035999046(27)) experimental results.

Remark:

If we compare Morel and Parker results (calculation from formula (1)) we find an accuracy based hint of a „running α “ which can not be the case from a theoretical point of view including the elementary charge (e) experiments. This justifies a new way of thinking beyond the SM just to avoid running α numbers from a theoretical point of view respecting the two experiments accuracy.

II. Hypothesis:

The mass $m_{eE}(\text{Rb})$ (from experiment) of the electron escaping the rubidium atom $m(\text{Rb})$ with ratio $m(\text{Rb})/m_{eE}(\text{Rb})$ (from literature) or mass $m_{eE}(\text{Cs})$ (from experiment) escaping the Caesium Atom with ratio $m(\text{Cs})/m_{eE}(\text{Cs})$ (from literature), involved in the process, must be different in value due to the ionisation energy respectively is our new way of thinking.

Hypothesis:

$m_{eE}(A)$, restmass released, depends on the ionisation energy $R_y(A)$ of the atom A under investigation.

II.1 Conclusion from Hypothesis:

If the electrons rest-mass $m_{eE}(A)$ increases depending on the process of ionisation then alpha decreases (so $1/\alpha$ increases) while using formula 1.

$$3 \quad \alpha^2 = 2 * (R_0/c) * m_e * (m_A/m_{eEA}) * (h/m_A)$$

$R_0 = R_y/m_{eH}$ (here m_{eH} (Codata value)) is introduced above only to discuss the hypothesis more clearly concerning the difference between $m_{eE}(H)$ and $R_y(H)$ and $m_{eE}(A)$ and $R_y(A)$.

$m_{eE}(H)$ is the electron rest-mass from ionisation of the hydrogen atom-experiment and $m_{eE}(A)$ the electron mass released from ionisation of atom Cs or Rb. So let us assume that the rest-mass of the escaping electrons $m_{eE}(A)$ are different in all the experiments available: ($m(\text{Cs}, 3.89\text{eV}) > m(\text{Rb}, 4.18\text{eV}, 27.3\text{eV}) > m(\text{He}, 24.6\text{eV}) > m(\text{H}, 13.6\text{eV})$) based on the difference to of the ionisation energy $E(A)$.

Notice the irregular jumps between the ionisation energies in eV!

II.2 Hypothesis applied

The restmass of the electron $m_{eE}(x_A)$ - measured within 5-experimental processes - are different and depend on the ionisation energy x (x : normalised number, $x = E(A)/E_0$ and $E_0 = 1\text{eV}$ used as a reference)! So does $\alpha(x)$!

$$4 \quad (1/\alpha(x))^2 = slope * x + (1/\alpha(0))^2$$

The change of the released mass $m_{eA}(x_A)$ escaping the atom produces running $\alpha(x_A)$ numbers.

III. Experimental alpha-Data available

Table 1 Comparison between 5-data-experiments and fit from (formula 4). The fit yields a $1/\alpha(0)$ number ($1/137.035999022$, blue line at zero). Data from Morel, Parker and predecessors.

	E(A) in eV	Calculation from fit	Experimental data	Reference
Theory	0	137.035999024	?	
Cs	3.8939	137.035999048	137.035999046(27)	Parker et al. (2018) [1]
Rb	4.1771	137.035999050	137.035999037(91)	Bouchendira(11) [5]
H	13.5984	137.035999114	137.035999084(21)	Codata (2020)
He	24.5873	137.035999188	137.035999190(330)	Yu (17) [6]
Rb (2.E)	27.2895	137.035999206	137.035999206(11)	Morel et al. (2020) [3]
He(2.E)	54.417	137.035999390	137035999550(640)	Smiciklas (10) [7]

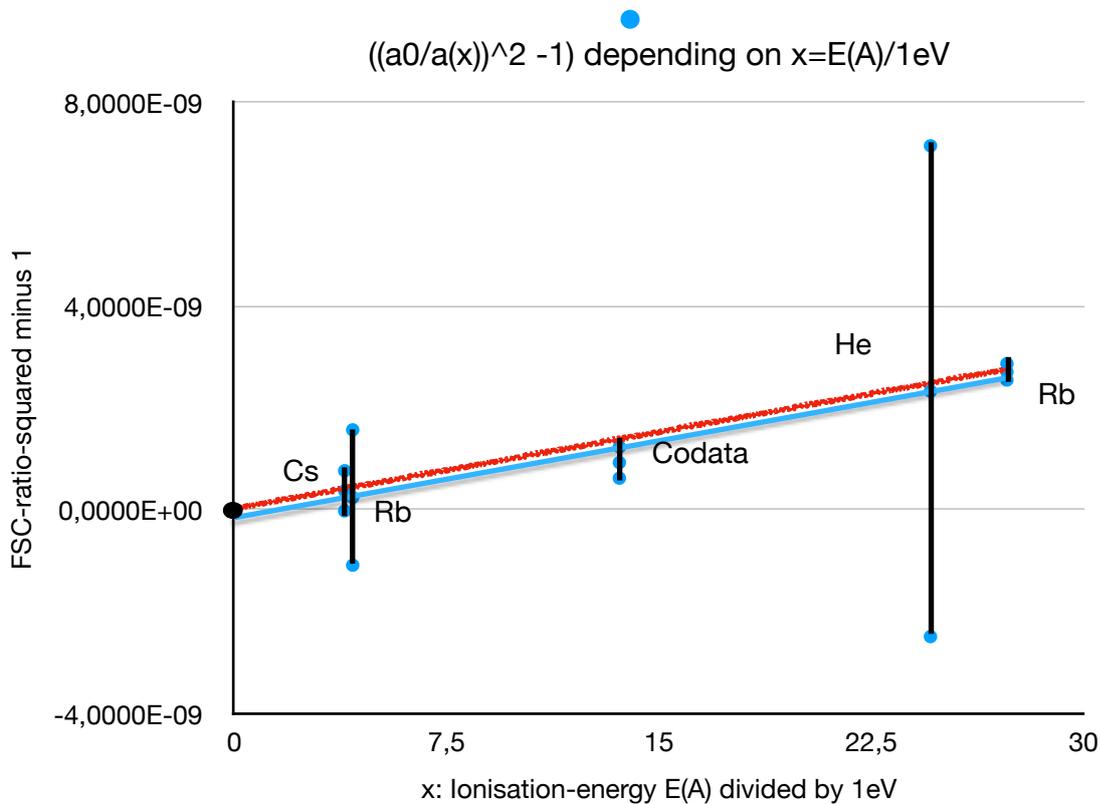


Figure 1 Experimental 5-data from table 1 (blue buttons) indicate a linear dependence concerning the ionisation energy $E(A)$ respectively. (red line-fit only Morel and Parker and here $1/\alpha(0)=137.035999024$ at zero, black button.)

III.1 Explanation of the „tension“ between alpha(A)-experiments

The hypothesis (influence of the ionisation energy on restmass $m_{eA}(X_A)$) is quite well fulfilled. See linear fit while using Morel and Parker high accuracy numbers only.

III.2 Conclusion:

The fit gives a basic FSC at zero ionisation energy.

$$5 \quad slope = \delta y / \delta x = 1.005E - 10$$

$1/\alpha(0)=137.035999024$ „from zero ionisation limit“ within the fit (red line).

So $\alpha(0)$ as fundamental constant can be used for calculation of the elementary charge (e) value to be compared with that from Codata.

$$6 \quad e^2 = 2\alpha \cdot h \cdot c \cdot \epsilon_0$$

$e(\alpha(0))=1.602176\mathbf{58}E-19As$ compared to $e(\text{Codata2020})=1.602176\mathbf{62}E-19As$ shows a tiny but significant difference.

It is also of great interest to have $\alpha(0)$ as an input number testing Standard Model predictions of $a_e(\alpha_0)$

So more experiments with different atoms and different ionisation energy should be done or re-measured with increasing accuracy to prove the new interpretation correct.

IV. Literature

- (1) **Ann. Phys. (Berlin) 2019, 531, 1800346**, Atom-Interferometry Measurement of the Fine Structure Constant, Chenghui Yu, Weicheng Zhong, Brian Estey, Joyce Kwan, Richard H. Parker, and Holger Muller
- (2) High-Accuracy Measurement of the Magnetic Moment Anomaly of the Electron Bound in Hydrogenlike Carbon, H. Häffner, T. Beier, N. Hermanspahn, H.-J. Kluge, W. Quint, S. Stahl, J. Verdú, and G. Werth **Phys. Rev. Lett. 85, 5308 – Published 18 December 2000**
- (3) Morel, L., Yao, Z., Cladé, P. *et al.* Determination of the fine-structure constant with an accuracy of 81 parts per trillion. **Nature 588, 61–65 (2020)**. <https://doi.org/10.1038/s41586-020-2964-7>, ($1/\alpha=137,035999206(11)$ (Rb), 2 Ionization energy)
- (4) Parker et al. (2018) Measurement of the fine-structure constant as a test of the Standard Model ($1/\alpha=137,035999046(27)$ (Cs), 1. Ionization energy) <https://science.sciencemag.org/content/360/6385/191> **Science 13 Apr 2018:Vol. 360, Issue 6385**, pp. 191-195 DOI: 10.1126/science.aap7706
- (5) Rym Bouchendira, Pierre Cladé, Saïda Guellati-Khélifa, François Nez, and François Biraben, **Phys. Rev. Lett. 106, 080801 – Published 24 February 2011** ($\alpha^{-1}=137.035999037(91)$ (Rb), 1. Ionization energy)
- (6) Y. R. Sun, and S.-M. Hu Precision Spectroscopy of Atomic Helium (2017 He $137,035999180(330)$), 2020. **Published by Oxford University Press** (<http://creativecommons.org/licenses/by/4.0/>)
- (7) A DETERMINATION OF THE FINE STRUCTURE CONSTANT USING PRECISION MEASUREMENTS OF HELIUM FINE STRUCTURE Marc Smiciklas, B.S., M.S. UNIVERSITY OF NORTH TEXAS August 2010
He: $\alpha^{-1} = 137.035\ 999\ 550(640)$.