About the synchronization effect between a clock situated in the origin of a rotating system and a laboratory clock

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Abstract

We show that the attempt by Corda to explain the results of the Mössbauer rotor experiments via introducing the effect of synchronization of clock in the origin of a rotating system and a laboratory clock contains mathematical error and must be rejected.

Keywords: Mössbauer rotor experiments, general theory of relativity, synchronization of clocks

1. Introduction

The problem of synchronization of clock in the origin of a rotating system with a laboratory clock had been pointed out by Corda [1] in his attempt to explain the origin of the extra energy shift (EES) between emitted and received radiation in a rotating system.

We remind that the EES has been revealed, next to the usual time dilation effect, through the re-analysis by our team [2] of the experiment by Kündig [3], followed by its confirmation in modern Mössbauer experiments in a rotating system [4-7].

For a co-rotating source of resonant radiation and a resonant absorber, the linear Doppler effect does not emerge (see, e.g. [8]), while the relative second order Doppler shift written to the accuracy of calculations up to c^{-2} is given by the general expression

$$\frac{\Delta E}{E} = -k\frac{u^2}{c^2}. \qquad (1)$$

Here, the minus sign corresponds to the case, where the source of radiation is fixed in the origin of a rotating system, while the resonant absorber is located at the edge of the rotor and has the tangential velocity u.

We remind that due to the relativistic dilation of time, the coefficient k in this equation ought to be equal to 1/2, and this result had indeed been reported in a series of experiments implemented soon after the discovery of the Mössbauer effect [3, 9-13]. However, as we have shown in [2], the corrected outcome of the data published by Kündig [3] and Champeney et al. [13] rather surprisingly yields the inequality

$$k \geq 0.6, \qquad (2)$$

and the difference from the classical relativistic prediction k=0.5 exceeds by at least 10 times the measurement uncertainty reported by the authors of the experiments [3, 9-13].

The finding (2) had been confirmed in two recent separate experiments conducted of our term that led to

$$k=0.66\pm0.03 \text{ [4, 5]} \qquad (3)$$

and

$$k=0.69\pm0.02 \text{ [6, 7]}. \qquad (4)$$

The results (2)-(4) indicate that the actual energy shift between an emitted and a received radiation in a rotating system is defined not only by the ordinary relativistic dilation of time for an orbiting resonant absorber, but does, in essence, include an additional effect which is responsible for the extra-energy shift between emission and absorption lines, and which constitutes about 30 % from the classically expected relativistic value k=0.5.

Thus, a disclosure of the origin of the EES became a topical problem – whereupon, an attempt to provide an interpretation of it emerged in ref. [1] and continued in subsequent publication by C. Corda [14]. According to him, the origin of the EES could be understood within the framework of the general theory of relativity (GTR), if the additional effect of clock synchronization between a resonance source (fixed on the rotational axis) and a detector of γ-quanta (resting in the laboratory frame) is taken into account. However, in section 2 we show that the calculation of this synchronization effect is based on an evident error, and in the corrected analysis, the rate of the clock in the origin of the rotating system and the rate of the laboratory clock remain identical to each other at any rotational frequency ω of the rotor. Thus, when both clocks are synchronized with each other before the rotor is run, they remain synchronized at any finite rotational frequency, too.

2. Mössbauer experiments in a rotating system: interpretation by Corda and his error

The goal of the paper by Corda [1] was to interpret the results (3), (4) under the framework of GTR. According to him, previous analyses of the Mössbauer rotor experiments, which predicted the value k=1/2 in eq. (1), "missed an important effect" – i.e., that of a clock synchronization between the spinning source (mounted on the rotor axis) and the detector of γ-quanta (located outside the rotor system). Thus, the detector is moving with respect to the origin of a rotating frame. Hence, according to Corda, for an actual determination of the coefficient k in eq. (1), the clock in the detector should have been synchronized with the clock in the origin; and this would give (according to him) an additional contribution to the energy shift, next to the energy shift between the resonant lines of the source and the absorber. Based on his calculations [1], this additional component of the relative energy shift is given by the equation

$$(\Delta E/E)_{\text{source-detector}}=-u^2/6c^2, \tag{5}$$

which thus must (according to Corda) be added to the conventional relative energy shift between the lines of the resonant source and the absorber

$$(\Delta E/E)_{\text{source-absorber}}=-u^2/2c^2. \tag{6}$$

Therefore, in Corda's view, the total relative energy shift measured in the Mössbauer rotor experiment should be defined as the sum of the energy shift components (5) and (6); i.e.

$$(\Delta E/E)_{\text{total}}=(\Delta E/E)_{\text{source-absorber}}+(\Delta E/E)_{\text{source-detector}}=-u^2/2c^2-u^2/6c^2=-2u^2/3c^2. \tag{7}$$

A comparison of eqs. (1) and (7) yields k=2/3, which is seemingly in a perfect agreement with the experimental results (3), (4).

Based on eq. (7), Corda concluded that the results (3), (4) represent a "*new, strong and independent proof of Einstein's general relativity*" [1].

However, in ref. [15] we have shown that this conclusion by Corda is fallacious, because the energy shift component (5), arising between the source and detector cannot be measured with any detector of γ-radiation, having a typical energy resolution of a few percents, which happens to be about 10 orders of magnitude larger than the relative energy shift (5) at sub-sound velocity u.

Nevertheless, Corda refused to accept this obvious factuality, and tried to defend his mix-up in ref. [14], where he appears to consent to the fact that the detector itself is insensitive to the energy shift component (5). Even so, he claimed that eq. (7) should nevertheless be implemented for an observer located in a laboratory frame, wherein we have "the final output of the measuring" [14]. In order to warrant this vague definition, Corda claims that "*…a total energy shift measured by an observer located in the fixed detector of γ-quanta is different from the one measured by an observer located in the rotating resonant absorber…"*. However, we have shown in ref. [16] that this assumption straightforwardly contradicts classical causality.

What is more, we will show below that this specification with respect to the Mössbauer effect methodology, in fact, even was not required, because the entire effect of synchronization of clocks introduced by Corda delineates an evident mathematical error and must be rejected.

In order to indicate the mathematical error by Corda, we point out that in the calculation of his synchronization effect between the clock in the detector and the clock in the origin of a rotational system, he has used eq. (10) of ref. [18] modified to the form

$$d\tau = dt'\left(1-\frac{r'^2\omega^2}{c^2}\right), \tag{8}$$

where dt' is the time increment at r', and ω is the angular rotation frequency. According to Corda [1], this equation "… *represents the proper time increment* $d\tau$ *on the moving clock having radial coordinate r' for values v<<c*."

In order to clarify better the limit of the applicability of eq. (8), we addressed to the original work by Ashby [17] that Corda references in his enterprise, and found out that the precursor of equation (8) (eq. (10) of [17]) is derived from the Langevin metric in a very particular case, where we deal with the process of synchronization of two distant clocks belonging to the rotating frame, via a slow transportation of a portable clock, dissiminating time. In such a case, the parameter v stands for the *velocity* of said portable clock, which should be assumed to be negligibly small, i.e., $v\to 0$. Then, in the indicated limit, the known expression for the proper time increment in the Langevin metric [17]

$$d\tau^2 = dt'^2\left[1-\left(\frac{\omega r'}{c}\right)^2 - \frac{2\omega r'^2\,d\varphi'}{c^2 dt'} - \left(\frac{d\sigma'}{cdt'}\right)^2\right] \tag{9}$$

can be substantially simplified via neglecting the terms $(d\sigma'/cdt')^2$ and $(\omega r'/c)^2$. (Here $d\sigma'^2 = dr'^2 + (r'd\varphi')^2 + dz'^2$, and r', z' and φ' are the cylindrical coordinates). Hence, we arrive at eq. (10) of [17],

$$d\tau = dt' - \frac{\omega r'^2\,d\varphi'}{c^2},$$

which further indeed yields eq. (8).

However, the approximation $v\to 0$ is obviously inapplicable to the detector of γ-radiation, which, for an observer in the origin of rotating systems, orbits with a finite tangential velocity $-\boldsymbol{\omega}\times\boldsymbol{r}'$, and its motion is described by the equations

$$r' = const,\ z' = 0,\ d\varphi' = -\omega dt'. \tag{10a-c}$$

Hence, substituting eqs. (10a-c) into the general equation (9), we obtain

$$d\tau = dt'. \tag{11}$$

This means that Corda unfortunately made a trivial blunder, and the rate of clock in the origin of a rotating system and the rate of laboratory clock are identical to each other. Therefore, the clock situated at the center of the rotor, being synchronized with a laboratory clock before running the rotor system, continues to remain synchronized with the laboratory clock at any frequency ω.

Thus, we conclude that the entire approach by Corda is erroneous, and the problem of a correct interpretation of the EES in the framework of GTR remains to be open.

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