*New Advances in Physics, Vol. 13, No. 1, January 2019, pp. 13-22*

# The YARK theory of gravity is completely ruled out by the Mössbauer rotor experiment

***Christian Corda***

***Abstract:*** *We show that, contrary to some claim in the literature, the so called YARK theory of gravity is completely ruled out by the Mössbauer rotor experiment.*

The name Mössbauer effect arises from the discovery in 1958 of resonant and recoil-free emission and absorption of gamma rays, without loss of energy, by atomic nuclei bound in a solid by the German physicist R. Mössbauer [1]. For such a discovery, Mössbauer was awarded the 1961 Nobel Prize in Physics. The Mössbauer effect is very important in various research fields in both physics and chemistry. In the present work, the so called Mössbauer rotor experiment will be discussed, see Figure 0.1.

Here, we indeed discuss a particular Mössbauer effect which works by using a detector orbited around a source of resonant radiation (or vice versa). The aim of this kind of experiments is to verify the relativistic time dilation for a moving resonant absorber which generates a relative energy shift between emission and absorption lines.

A famous experiment on the Mössbauer rotor effect was realized by Kündig [2]. Over the last years, Kündig's experiment has been reanalysed by a group of researchers [3, 4]. Such authors, first reanalysed in [3] the data of Kündig's experiment. Then, they realized their own Mössbauer rotor experiment [4]. In the data processing of the original experiment of Kündig [2], the research group found the presence of errors [3]. After the correction of such errors the authors of [3] found the value

$$\frac{\nabla E}{E} \simeq -k\frac{v^2}{c^2}, \tag{1}$$

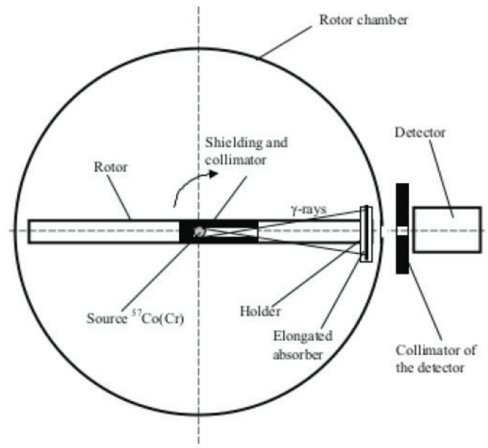


Figure 0.1: Scheme of the new Mössbauer rotor experiment, adapted from ref. [2]

where $k = 0.596 \pm 0.006$, instead of the standard general relativistic prediction $k = \frac{1}{2}$ due to time dilation. We use the terms general relativistic because the idea to use Einstein's general theory of relativity (GTR) in order to explain the Mössbauer rotor experiment has a long history, which started from the famous book of Pauli [5]. The key point for a general relativistic interpretation of the Mössbauer rotor experiment is *Einstein's equivalence principle* (EEP) which states the equivalence between the gravitational "force" and the *pseudo- force* experienced by an observer in a non-inertial frame of reference [6 - 9]. The Mössbauer rotor experiment represents a particular case of the EEP [6 - 9]. Thus, one is enabled to use a full general relativistic treatment in order to analyse the theoretical framework of the Mössbauer rotor experiment directly in the rotating frame of reference [6 - 9].

In any case, the result of k strongly different from $k_1 = \frac{1}{2}$ was a puzzling issue. The authors of [3] stressed that, on one hand, the deviation of *k* in Eq. (1) from $k = \frac{1}{2}$exceeds by almost 20 times the measuring error. On the other hand, they clarified that such a deviation did not depend on the influence of rotor vibrations and/or on other kinds of disturbing factors. The very good methodology applied by Kündig [2] excluded indeed various potential disturbing factors. That methodology concerns a first-order Doppler modulation of the energy of $\gamma$-quanta on the rotor at each fixed frequency of rotation [2]. Thus, Kündig's experiment can be surely considered the most precise among other similar experiments [10 - 14]. In fact, the other cited experiments [10 - 14] measured only the count rate of detected $\gamma$-quanta as a function of the frequency of rotation.

In [3], the authors have also shown that the experiment in [13] confirms the supposition $k > 0.5$. The experiment in [13] has indeed presented much more data than the ones in [10 - 12] and in [14]. In order to realize a better investigation of the results in [2], the authors realized their own experiment [4]. In this new experiment, the authors repeated neither the scheme of the original Kündig experiment [2], nor the schemes of other known experiments on the subject in [10 - 14]. In that way, they obtained a completely independent information on the value of $k$ in Eq. (1). In fact, the authors of [4] refrained from the first-order Doppler modulation of the energy of $\gamma$-quanta. Thus, the uncertainties in the realization of this method have been completely excluded [4]. A scheme similar to the experiments in [10 - 14] has been realized also in [4]. Consequently, the count rate of detected $\gamma$-quanta N has been measured as a function of the frequency of rotation $\nu$. An important difference with respect to the experiments in [10 - 14] is that, in [4], the influence of chaotic vibrations on the measured value of $k$ has been evaluated. The authors of [4] indeed used a method involving a joint processing of the data collected for two selected resonant absorbers with the specied difference of resonant line positions in the Mössbauer spectra. They obtained the value $k = 0.68 \pm 0.03$ as final result [4]. Hence, the experiment in [4] was an important confirmation that the coeficient $k$ in Eq. (1) must substantially exceed $\frac{1}{2}$. . The general scheme of the Mössbauer rotor experiment in [4] can be seen in Figure 0.1.

Based on the above cited EEP, the theoretical framework of the Mössbauer rotor experiment has been directly reanalysed in the rotating frame of reference in our works [6 - 9] by using a full general relativistic treatment. In [6 - 9] it has been indeed shown that previous analyses in the literature [10 - 14] missed an important effect of clock synchronization between the frame of the laboratory and the rotating frame. Hence, the correct general relativistic prevision gives $k \simeq \frac{2}{3}$ [6 - 9]. This results is completely consistent with the new experimental results in [4]. The important physical interpretation is that the general relativistic interpretation in [6 - 9] means that the new experimental results of the Mössbauer rotor experiment in [4] result a new, strong and independent, proof of the GTR. Remarkably, the results on the Mössbauer rotor experiment in [6 - 9] have been awarded with an Honorable Mention at the Gravity Research Foundation 2018 Awards for Essays on Gravitation [6].

It is important emphasizing that various papers in the literature (included ref. [14] published in Phys. Rev. Lett.) missed the additional effect of clock synchronization [2 - 4, 10 - 14]. This generated some claim of invalidity of relativity theory and/or some attempts to explain the experimental results through non-conventional or exotic effects [3, 4, 15]. Of course, such claims must be ultimately rejected.

Despite our analysis in [6 - 9] is in perfect agreement with the new experimental results of the Mössbauer rotor experiment in [4], our result has been criticized in [16, 17]. That criticism to our analysis in [6 - 9] concerns the issue that, in the opinion of the authors of [16, 17], the Mössbauer rotor experiment cannot detect the second effect of clock synchronization. The key issue of the criticism in [16, 17] should be that the extra energy shift due to the clock synchronization is of order $10^{-12}$... $10^{-13}$ and cannot be detected by the detectors of $\gamma$-quanta which are completely insensitive to such a very low order of energy shifts [16]. In addition, in [16] the authors claimed to have shown that the extra energy shift can be explained in the framework of an alternative gravitational theory proposed by themselves. They self-called such a theory as YARK theory of gravity from the initials of their proper surnames. They also insinuated that such a new theory should replace the GTR as the correct theory of gravity. Actually, we have recently dismissed such strange and erroneous claims, by showing in [18] that the YARK theory is unscientific because, being a non metric theory, it macroscopically violates EEP, which has today a strong, indisputable, empiric evidence [18, 19]. In addition, we have also shown in [20] that, contrary to the claims in [21], the YARK theory can reproduce neither the LIGO's GW150914 signal nor the other LIGO's detections of gravitational waves.

Returning to the Mössbauer rotor experiment, we have shown in [8] that the authors of [16] had a misunde firstanding of our theoretical analysis in [7] and in [9] that the criticisms in [16, 17] are due to very elementary mistakes, misunderstanding and flaws of basic physics. In particular, in their criticisms the authors of [16, 17] have implicitly stated that [9]

- An apparatus realized to measure a time dilation can measure a particular time dilation but it cannot measure a second time dilation which has the same order of magnitude of the first time dilation.
- The result of a classical (i.e. non-quantum) experiment depends on the way in which the experiment is realized.

Of course, both of the two statements above are completely unscientific, see [9] for details. In any case, after reading our analysis in [9], the authors of [16, 17] wrote a new paper with other elementary mistakes [22], by adding further confusion. Thus, in the following we will correct those new mistakes and we will clarify the situation.

In [22] the authors claim that there is no effect of clock synchronization between the frame of the laboratory and the rotating frame. In fact, they verbatim claim that [22] "the clock in the origin of a rotating system and a laboratory clock being synchronized to each other before the rotor run both stay synchronized at any given angular velocity $\omega$” and, as a consequence, the so-called synchronization effect by Corda completely disappears [?]. This is a very elementary mistake. In order to clarify and correct such a mistake, let us review the derivation of the effect of clock synchronization following [9]. In the starting laboratory frame, one considers the line-element [6 - 9].

$$ds^2 = c^2dt^2 - dr^2 - r^2d\phi^2 - dz^2. \tag{2}$$

The transformation to a frame of reference $\{t', r', \phi' z'\}$ which rotates with an uniform angular rate $\omega$ with respect to the starting laboratory frame is [6 - 9]

$$t = t' \quad r = r' \quad \phi = \phi' + \omega t' \qquad z \models z' \ . \tag{3}$$

Thus, from Eq. (2) one gets the famous Langevin metric in the rotating frame [6 - 9]

$$ds^2 = \left(1 - \frac{r'^2\omega^2}{c^2}\right) c^2dt'^2 - 2\omega r'^2 d\phi' dt' - dr'^2 - r'^2 d\phi'^2 - dz'^2. \tag{4}$$

The EEP enables one to interpret the line element of Eq. (4) in terms of a curved space-time in presence of a static gravitational field [6 - 9]. One recalls that, in a gravitational field, the rate $d\tau$ of the proper time is related to the rate $dt'$ of the coordinate time by [9, 23]

$$d\tau^2 = g_{00}dt'^2. \tag{5}$$

From the first of Eqs. (3), i.e. $t = t'$, one gets immediately from Eq. (5)

$$d\tau^2 = g_{00}dt^2. \tag{6}$$

Thus, as in a Minkowskian space-time the proper time is equal to the coordinate time, Eq. (6) immediately dismisses the elementary mistake of the authors of [22] that a the clock in the origin of a rotating system and a laboratory clock being synchronized to each other before the rotor run both stay synchronized at any given angular velocity $\omega$”.

On the other hand, in Eq. (4) one finds $g_{00} = \left(1 - \frac{r'^2\omega^2}{c^2}\right)$ Thus, Eq. (5) can be rewritten as [9]

$$c^2d\tau^2 = \left(1 - \frac{r'^2\omega^2}{c^2}\right) c^2dt'^2. \tag{7}$$

Then, using Eq. (3) one gets[9]

$$c^2 dt'^2 = c^2 dt^2 = dr^2 = dr'^2, \tag{8}$$

where the equality

$$c^2 dt^2 = dr^2 \tag{9}$$

depends on the issue that light propagates in the radial direction in the laboratory frame (the source is indeed at rest in that frame). Thus, one has $d\phi' = dz' = 0$ in Eq. (4) and, by inserting the condition of null geodesics $ds = 0$ in the same equation, one immediately obtains Eq. (9). Then, Eq. (7) becomes [9]

$$c^2 d\tau^2 = \left(1 - \frac{r'^2\omega^2}{c^2}\right) dr'^2. \tag{10}$$

Taking the root square of this last equation one obtains [9]

$$c d\tau = \sqrt{1 - \frac{r'^2\omega^2}{c^2}} dr'. \tag{11}$$

One well approximates Eq. (11) with [6 - 9]

$$c d\tau \simeq \left(1 - \frac{1}{2}\frac{r'^2\omega^2}{c^2} + ....\right) dr'. \tag{12}$$

Eq. (12) gives the second contribution of order $\frac{v^2}{c^2}$ to the variation of proper time [6 - 9]

$$c\Delta\tau_2 = \int_0^{r'_1} \left(1 - \frac{1}{2}\frac{(r'_1)^2\omega^2}{c^2}\right) dr' - r'_1 = -\frac{1}{6}\frac{(r'_1)^3\omega^2}{c^2} = -\frac{1}{6} r'_1 \frac{v^2}{c^2}. \tag{13}$$

We stress that $r'_1 \simeq c\tau$ is the radial distance between the source and the detector. Thus, the second contribution of order $\frac{v^2}{c^2}$ to the blueshift is given by [6 - 9]

$$z_2 \equiv \frac{\Delta\tau_2}{\tau_1} = -k_2 \frac{v^{\ 2}}{c^2} = -\frac{1}{6}\frac{v^2}{c^2}. \tag{14}$$

Then, one obtains $k_2 = \frac{1}{6}$ which is the second contribution to $k$. By recalling that the first general relativistic contribution to $k$ given by the gravitational blueshift is $k_1 = \frac{1}{2}$ [5 - 14] one get

$$k = k_1 + k_2 = \frac{1}{2} + \frac{1}{6} = 0.\bar{6}, \tag{15}$$

which is completely consistent with the experimental result $k = 0.68 \pm 0.03$ in [4].

Now, the authors of [22] claim that the above reviewed derivation of the additional effect of clock synchronization is wrong. Their argument is that we assumed that light emitted from the origin of the rotating system propagates along the radial direction. Instead, one can easily check that we correctly assumed that light actually propagates in the radial direction in the laboratory frame. Thus, the argument raised by the authors of [22] against the above reviewed derivation of the additional effect of clock synchronization is pure nonsense. For the sake of correctness, we stress that we considered only radial propagation of light in the rotating system in our previous works [6 - 8]. Actually, this is NOT a mistake. In fact, despite propagation of light in the rotating frame is not radial, the gravitational field has pure radial direction. This implies that the momentum of photons in the rotation direction, which is perpendicular to the radial direction, is conserved. As a consequence, the two blueshift effects works ONLY in the radial direction in the rotating frame. In fact, despite propagation of light in the rotating frame is not radial, the formula which governs the effect of clock synchronization, i.e. Eq. (10) depends ONLY on the radial coordinate in the rotating frame.

On the other hand, the authors of [22] claim that, even admitting that the additional effect of clock synchronization exists, it cannot be detected by a Mössbauer rotor apparatus. They raised two points concerning this issue:

1. The relative statistical error $\delta_s$ of the accumulated number N of the detected signals in a Mössbauer rotor experiment must be too small in order to be less than the quantity representing the total blushift of light which is [6 - 9]

$$z = -\frac{2}{3}\frac{v^2}{c^2}. \tag{16}$$

   Unbelievably, the authors of [22] do not realize that the quantity of Eq. (16) is EXACTLY the quantity that is detected by the Mössbauer rotor experiment and that they claim can be explained by YARK theory! Thus, they are claiming that, despite the Mössbauer rotor experiment works very well, it has no enough sensitivity to work and it cannot detect a signal which, instead, has been regularly detected!

2. The quantity

$$z_1 = -\frac{1}{2}\frac{v^2}{c^2} \tag{17}$$

corresponding to the traditional effect of the gravitational blueshift cannot be detected by a Mössbauer rotor experiment because the corresponding variation of the number of the detected signals $\frac{\triangle N}{N}$ in Mössbauer rotor experiments is about 10 orders of magnitude larger. Again, the authors of [22] do not realize that the quantity of Eq. (17) is of the same order of magnitude the quantity of Eq. (16) which is EXACTLY the quantity that is detected by the Mössbauer rotor experiment and that they claim can be explained by YARK theory. Thus, in claiming that the quantity of Eq. (17) cannot be detected, they are still claiming that the Mössbauer rotor experiment CANNOT work!

Notice that in [22] the authors claims that we have total misunderstanding of experimental physics and Mössbauer spectroscopy in particular. Instead, it is quite evident that they are the authors of [22] who have a strong lack of knowledge and understanding of elementary physics.

It is important stressing the following. The YARK theory in [16, 17] predicts a total value of $\frac{2}{3}$ for the coeficient k in equation (1). But, in [16, 17] the effect of clock synchronization has NOT been taken into due account. Thus, by considering also this additional effect, if one uses Eqs. (14), one gets the correct value of

$$k = \frac{2}{3} + \frac{1}{6} = \frac{5}{6} \tag{18}$$

for the YARK theory in [16, 17]. This result is in TOTAL contrast with the experimental results in [4]. Thus, contrary to the claims in [16, 17], the YARK theory is COMPLETELY RULED OUT by the Mössbauer rotor experiment.

Finally, we stress that further unscientific bla bla bla by the authors of [22] on the issue that the effect of clock synchronization cannot be detected will be merely ignored. It is indeed very evident, and also understandable by high school students, that, as the effect of clock synchronization is of the same order of magnitude of the total effect, EVERY criticism against its detectability can be easily applied against the detectability of the total effect. In other words, claiming that the effect of clock synchronization cannot be detected it is completely equivalent to claim that the Mössbauer rotor experiment cannot work.

## *References*

[1] R. L. Mössbauer, Zeitschrift für Physik A (in German) 151, 124 (1958).

[2] W. Kündig, Phys. Rev. 129, 2371 (1963).

[3] A. L. Kholmetskii, T. Yarman and O. V. Missevitch, Phys. Scr. 77, 035302 (2008).

[4] A. L. Kholmetskii, T. Yarman, O.V. Missevitch and B. I. Rogozev, Phys. Scr. 79, 065007 (2009).

[5] W. Pauli, Theory of Relativity, Pergamon Press, London (1958).

[6] C. Corda, Int. Journ. Mod. Phys. D 27, 1847016 (2018).

[7] C. Corda, Ann. Phys. 355, 360 (2015).

[8] C. Corda, Ann. Phys. 368, 258 (2016).

[9] C. Corda, https://www.preprints.org/manuscript/201904.0219/v2 (2019).

[10] H. J. Hay, in Proc. 2nd Conf. Mössbauer Effect, ed A Schoen and D M T Compton (New York: Wiley) p 225 (1962).

[11] T. E. Granshaw and H. J. Hay, in Proc. Int. School of Physics, 'Enrico Fermi' (New York: Academic) p 220 (1963).

[12] D. C. Champeney and P. B. Moon, Proc. Phys. Soc. 77, 350 (1961).

[13] D. C. Champeney, G. R. Isaak and A. M. Khan, Proc. Phys. Soc. 85, 583 (1965).

[14] H. J. Hay et al, Phys. Rev. Lett. 4, 165 (1960).

[15] V. O. de Haan, Jour. Comp. Meth. Scien. Eng., 13, 51 (2013).

[16] T. Yarman, A. L. Kholmetskii, and M. Arik, Eur. Phys. Jour. Plus 130, 191 (2015).

[17] A. L. Kholmetskii, T. Yarman, O. Yarman, M. Arik, Ann. Phys. 374, 247 (2016).

[18] C. Corda, Eur. Phys. J. Plus 133, 456 (2018).

[19] C. M. Will, Living Rev. Rel. 17, 4, (2014).

[20] C. Corda, Symmetry 10, 558 (2018).

[21] T. Yarman, A. L. Kholmetskii, O. Yarman, C. B. Marchal, M. Arik, Can. Journ. Phys., 95 (10), 963 (2017).

[22] A. Kholmetskii, T. Yarman, O. Yarman, and M. Arik, DOI: 10.13140/RG.2.2.19392.38407 (2019).

[23] L. Landau and E. Lifsits, Classical Theory of fields (3rd ed.). London: Pergamon. ISBN 0-08-016019-0. Vol. 2 of the Course of Theoretical Physics (1971).