Comment on Eur. Phys. J. Plus 133, 261 (2018) by Kholmetskii et al. (The YARK theory of gravity is wrong)

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October 18, 2018

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Abstract

We show that the YARK theory of gravity, proposed in Eur. Phys. J. Plus 133, 261 (2018) by Kholmetskii et al. and in previous papers of the same research group is wrong.

PACS numbers: 04.20.-q; 04.20.Cv; 04.50.Kd.

Despite it is well known that completely non-metric gravitational theories macroscopically violate Einstein’s equivalence principle (EEP), in an astonishing way, various papers on a completely non-metric gravitational theory, today self-called the YARK theory of gravitation from the initials of the proper surnames of its authors, have been recently published in various journals [1 - 15], included Eur. Phys. J. Plus [1 - 3]. We recall that the YARK theory of gravitation has been originally proposed by T. Yarman in Foundation of Physics [10]. This happened in the well known period of time in which Foundation of Physics published a lot of wrong and non-standard results, before G. ’t Hooft’s management [11]. After that, various papers on the YARK theory of gravitation have been published by T. Yarman and collaborators (O. Yarman, A. L. Kholmetskii and M. Arik. Hereafter we will refer to them as the YARK group) [1 - 9, 11 - 15]. In all the cited papers, the YARK group also insinuated that the YARK theory of gravitation should replace Einstein’s GTR and that the GTR has various problems [1 - 15]. In addition, the YARK theory of gravitation should be in agreement with various experiments on earth and astrophysical observations [1 - 15].
Let us start our discussion by recalling that EEP has today a strong, unchallengeable empiric evidence [16]. The weak equivalence principle (WEP), which is included in the EEP, states that the mass of the body is proportional to its weight [16], or, alternatively, that the trajectory of a freely falling test mass (i.e. a mass which is not acted upon by such forces as electromagnetism and too small to be affected by tidal gravitational forces) is independent of the mass internal structure and composition [16]. The WEP also states the *Universality of Free Fall*, which means that all the bodies fall with the same acceleration [16]. The EEP is a more powerful concept stating that [16]:

a) WEP is valid;

b) the outcome of any local non-gravitational experiment is independent of the velocity of the freely-falling reference frame in which such an experiment is performed (local Lorentz invariance, LLI);

c) the outcome of any local non-gravitational experiment is independent of where and when in the universe such an experiment is performed (local position invariance, LPI).

Thus, it is a very natural and intuitive statement that if EEP is valid, then gravitation must be a “curved space-time” phenomenon [16]. This means that the effects of gravitation are completely equivalent to the effects of living in a curved space-time [16]. In other words, gravity is not a force. Instead, it is inertia in a curved space-time manifold [17]. Thus, one sees that, if EEP is valid, then in local freely falling frames, one needs the laws governing experiments to be independent of the velocity of the frame (LLI), with constant values for the various atomic constants (in order to guarantee LPI) [16]. The only laws of Nature that fulfill this are the ones being compatible with the special theory of relativity, such as Maxwell’s equations of electromagnetism, and the standard model of particles [16]. In addition, in a local freely falling frame, test masses appear to be not accelerated, and then moving on straight lines [16]. Such *locally straight* lines obviously correspond to *geodesics* in a curved space-time [16]. The strong, unchallengeable consequence of this argument is that the only viable theories of gravity are the metric theories of gravity, or possibly theories that are metric apart from very weak or short-range non-metric couplings [16][17]. We stress that there is a rigorous mathematical demonstration of our last statement. Let us assume:

1. The existence of a continuous space-time manifold.

2. The validity of EEP.

Then, following [18][19], one supposes that no particles are accelerating in the neighborhood of a point-event with respect to a freely falling coordinate system $(X^\mu)$. Setting $T = X^0$ we can write [18][19],

$$\frac{d^2 X^\mu}{dT^2} = 0,$$

(1)

which is locally applicable in free fall. Now, the chain rule gives [18][19]...
\[
\frac{dX^\mu}{dT} = \frac{dx^\nu}{dT} \frac{\partial X^\mu}{\partial x^\nu}.
\] (2)

If we differentiate eq. (2) with respect to \(T\) we get \[18, 19\]
\[
\frac{d^2 X^\mu}{dT^2} = \frac{d^2 x^\nu}{dT^2} \frac{\partial X^\mu}{\partial x^\nu} + \frac{dx^\nu}{dT} \frac{\partial^2 X^\mu}{\partial x^\nu \partial x^\alpha}.
\] (3)

Let us combine eqs. (1) and (3). Then we obtain \[18, 19\]
\[
\frac{d^2 x^\nu}{dT^2} \frac{\partial X^\mu}{\partial x^\nu} = -\frac{dx^\nu}{dT} \frac{dx^\alpha}{dT} \frac{\partial^2 X^\mu}{\partial x^\nu \partial x^\alpha}.
\] (4)

If one multiplies both sides of eq. (4) by \(\frac{\partial x^\lambda}{\partial X^\mu}\) one obtains \[18, 19\]
\[
\frac{d^2 x^\lambda}{dt^2} = -\frac{dx^\nu}{dt} \frac{dx^\alpha}{dt} \left[ \frac{\partial^2 X^\mu}{\partial x^\nu \partial x^\alpha} \frac{\partial x^\lambda}{\partial X^\mu} \right].
\] (5)

By putting \(t = x^0\) and by using again the chain rule, one can eliminate \(T\) in favor of the coordinate time \(t\) obtaining \[18, 19\]
\[
\frac{d^2 x^\lambda}{dt^2} = -\Gamma^\lambda_{\nu \alpha} \frac{dx^\nu}{dt} \frac{dx^\alpha}{dt} + \Gamma^0_{\nu \alpha} \frac{dx^\nu}{dt} \frac{dx^\alpha}{dt} \frac{dx^0}{dt},
\] (6)

We recall that the bracketed terms involving the relationship between local coordinates \(X\) and general coordinates \(x\) are functions of the general coordinates \[18, 19\]. In that way, eq. (6) gives immediately the geodesic equation of motion using the coordinate time \(t\) as parameter \[18, 19\]
\[
\frac{d^2 x^\lambda}{ds^2} = -\Gamma^\lambda_{\nu \alpha} \frac{dx^\nu}{ds} \frac{dx^\alpha}{ds} + \Gamma^0_{\nu \alpha} \frac{dx^\nu}{ds} \frac{dx^\alpha}{ds} \frac{dx^0}{ds},
\] (7)

Thus, we have shown that the two assumptions of the existence of a space-time manifold and of the validity of EEP rigorously imply that the gravitational motion must be geodesics. In other words, the correct gravitational theory must be a metric theory (or a possibly theory that is metric apart from very weak or short-range non-metric couplings \[16\], but this is NOT the case of YARK theory). We stress that the YARK group did not understand this key point in \[5\]. In fact, in \[5\] they verbatim claim that “said derivation (i.e. the above one) is exclusively restricted to the domain of a purely metric theory”. This is incorrect. We indeed did NOT assume that the gravitational theory must be metric. We assumed ONLY the existence of a continuous space-time manifold and the validity of EEP. Through our rigorous mathematical computation we
have shown that these two assumptions imply that the gravitational theory must be purely metric. In other words, this was a conclusion and a result. It was NOT an assumption, contrary to the claims of the YARK group in [5]. In addition, in [5] the YARK group generated further confusion by verbatim adding that “in YARK theory the derivatives $\frac{\partial X^\mu}{\partial x^\nu}$ already do not depend explicitly on spatial coordinates, but only on the static gravitational binding energy.” This is another basic mistake which is connected with the issue that the YARK group claims that YARK theory permits to localize the gravitational energy [1 - 15]. In the opinion of the YARK group the gravitational energy should remain a non-vanishing quantity in all plausible frames of reference [1 - 15]. This should permit to write down, explicitly, a stress-energy tensor for the gravitational field [1 - 15]. Clearly, the YARK group does not understand the real meaning of EEP. In fact, another consequence of EEP is that one can always find in any given locality a reference’s frame (the local Lorentz reference’s frame) in which ALL local gravitational fields are null. No local gravitational fields means no local gravitational energy-momentum and, in turn, no stress-energy tensor for the gravitational field [17]. Also in this case, the YARK group claims that this statement is again strictly applicable only to metric theories, as is the case with the GTR [5]. This is again wrong. In fact, it is well known that this is a mere consequence of Einstein’s ‘happiest thought’ that a freely falling body has not weight [20]. Einstein’s ‘happiest thought’ is indeed at the foundation of both of WEP and EEP. In other words, EEP has two rigorous consequences:

* Gravitational motion must be geodesic.

** The gravitational energy cannot be localized.

Both of points * and ** are consequences of EEP and, in turn, one does NOT need the assumption that a gravitational theory must be metric to verify points * and **. The metric behavior of a gravitational theory is a consequence of point * instead of an a priori assumption.

Clearly, based on the extreme precision on which the EEP is today tested and verified [16], the demonstration that we have reviewed above - i.e. that geodesic motions arise from the EEP - ultimately rules out YARK theory. In fact, that theory is founded on the absence of curvature [1 - 15] and so has a non-viable behavior. In other words, it is wrong. Despite the claims of the YARK group that the YARK theory of gravitation should be in agreement with various experiments on earth and astrophysical observations [1 - 15] (but in the following we will show that the YARK group is basically wrong in its YARK interpretation of the first gravitational wave signal detected by LIGO [22]), the YARK theory of gravitation is indeed in macroscopic contrast with the strongest observational constrain that a gravitational theory must satisfy, that is the EEP, which is founded on tons of experimental data [10]. Recently, we discussed this issue in some private communications with the leader theorist of the YARK group, i.e. T. Yarman [23]. T. Yarman honestly admitted that the above derivation is correct, but he now claims that it is the EEP which, in his opinion, does not work [23]. T. Yarman’s opposition to the EEP is the following. He claims the the ratio between the gravitational mass and the inertial mass,
i.e. \( K = 1 \)
\[
\frac{m_g}{m_i} = K
\] (9)
is not universal, despite the quantity \( K \) is today tested with the enormous precision of 1 part in \( 10^{14} \) by experiments \[24, 25\]. T. Yarman claims indeed that all the experiments concerning the ratio between the gravitational mass and the inertial mass, starting from the historical experiments of Eötvös \[20\] and the subsequent \[27, 28\] till the most recent ones \[24, 25\], have been misinterpreted by the scientific community \[23\]. He thinks that the experiments \[25 - 29\], and other ones, permit only to test the proportionality between the gravitational mass and the inertial mass rather than testing their effective equivalence \[24\]. In other words, T. Yarman claims that, in order to adopt \( K = 1 \) in Eq. (9), one has further to assume that \( K \) is a universal constant, without yet any rigorous experimental ground behind it \[23\]. In addition, he claims to have shown that it is instead \[23\]
\[
K = 1 - \frac{v^2}{c^2},
\] (10)
being \( v \) the velocity of the mass with respect to the chosen reference frame and \( c \) the speed of light. In fact, T. Yarman claims to have shown that the gravitational mass is given by \[23\]
\[
m_g = m_0 \exp(-\alpha) \sqrt{1 - \frac{v^2}{c^2}}
\] (11)
and that the inertial mass is given by
\[
m_i = m_0 \exp(-\alpha) \sqrt{1 - \frac{v^2}{c^2}}
\] (12)
where \( m_0 \) is the rest mass of the object at hand, in free space, and \( \alpha = \frac{GM}{c^2} \), being \( M \) the source of the gravitational field, \( G \) the Newtonian gravitational constant and \( r \) the distance of the moving mass from the source of the gravitational field. We immediately recognize that \( \gamma \equiv \sqrt{\frac{1}{1 - \frac{v^2}{c^2}}} \) is the well known Lorentz factor of the special theory of relativity (STR) \[29\]. Thus, setting \( M = 0 \) in Eq. (12), one immediately gets
\[
m_i = m_0 \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}
\] (13)
which is the traditional inertial mass of the STR \[29\]. In any case, even assuming that T. Yarman is correct (and we think that he is not), he misses a fundamental point here. The EEP has local behavior. In a local Lorentz frame it is \( v = 0 \) and one immediately obtains \( K = 1 \) in Eqs. (9) and (10). In other words, a free falling observed cannot distinguish between gravitational motion and inertial motion even assuming that T. Yarman’s analysis in \[23\] is correct. Therefore Einstein’s ‘happiest thought’ \[20\] is ultimately confirmed also in this
case. Hence, T. Yarman’s analysis in [23] cannot invalidate the above rigorous analysis that the EEP implies the geodesic motion [25] which, in turn, ultimately rules out the YARK theory of gravitation. It is also useful adding the following considerations. As it is not Lorentz invariant, within the STR the concept of inertial mass is dubious and/or ambiguous. Despite such difficulties (to attribute a value to inertial mass in the STR), we think that it still remains a description of the resistance of an object to change its proper velocity. Such a resistance becomes dependent on the frame of reference, see Eq. (13). On one hand, this makes the concept of inertial mass of little practical use in the STR. On the other hand, it does not damage the underlying idea of what it really represents.

Finally, we discuss the claims of the YARK group that the YARK theory can predict everything what is predicted through LIGO signals [9]. Actually, in [9] we find that in the the YARK theory the two arms are altered in the same way (and not depending on the direction of the incoming perturbation). This is well known to be an elementary mistake. In fact, the LIGO signal is given by the phase difference between the two interferometer’s arms, see for example [30]. Thus, if the two arms are altered in the same way (and not depending on the direction of the incoming perturbation) LIGO would not produce any output. This is a further proof that the YARK theory of gravity is wrong.

Conclusion remarks
In this Comment we have shown that the YARK theory of gravity, proposed in [1 - 15] is wrong for two important reasons. First, it is not consistent with the EEP; second, contrary to the claims in [9], it cannot predict everything what is predicted through LIGO signals. We hope that this Comment will prevent future publications on the wrong YARK theory of gravity in Eur. Phys. J. Plus and in other journals.

Acknowledgements
It is a pleasure to thank the Editor in Chief of Eur. Phys. J. Plus, Prof. Paolo Biscari, for inviting us to write this Comment. The author also thanks Mr. T. Yarman for private discussions on the issues of this Comment and an unknown referee for useful comments.

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