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# LIGO's "GW150914 signal" reproduced under YARK theory of gravity

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**Abstract.** We provide an alternative explanation of the widely publicized "GW150914 event" in the framework of Yarman-Arik-Kholmetskii (YARK) gravitation theory beyond the hypothesis about gravitational waves (GWs). According to YARK, the coalescence of super-massive bodies in a binary system would induce a related alteration of the respective wavelengths of the laser beams used in the LIGO Michelson-Morley interferometer, and our numerical results well match the GW150914 interference pattern without involving any GWs hypothesis. In addition, the binary merger necessitates a rest mass decrease in YARK (which we calculated to be about 3.1 solar masses) that should be released via electromagnetic radiation emission. Due to a finite (though tiny) rest mass of the photon in YARK theory, there should be a time lag between the arrival of gravitation perturbation and electromagnetic signal to Earth, which substantially depends on the particular value of the photon rest mass, and lies in the range between few years and few hundred years. Thus, at the moment, YARK is the only alternative to GTR, which provides its own interpretation of the LIGO signals without involving the hypothesis about GWs.

## 1. Introduction

During last years, LIGO Scientific Collaboration (LSC) announced few events of detection of gravitational waves (GWs) as predicted in GTR, and the first such signal dating from 14 September 2015, and called "the GW150914 event" [1], remains the most intensive. It resulted from the merger of two black holes (BHs) at a distance of  $410_{-180}^{+160}$  Mps from Earth.

In spite of this, it is actually impossible – given such a weak signal – to arrive at any conclusions about the polarization of the alleged GWs, let alone confirm their tensorial character as originally derived through GTR [2]. Under these circumstances, two important arguments are advanced in favor of a confirmatory interpretation of the LIGO experiment:

1. The amplitude and the frequency of the GW150914 signal correspond, with a good precision, to the numerical simulations carried out within the framework of GTR.
2. The mass deficit of about 3 Solar masses ( $M_s$ ) between the sum of the masses of the progenitor BHs ( $36_{-4}^{+5} M_s$ , and  $29_{-4}^{+4} M_s$ ) and the resultant daughter BH ( $62_{-4}^{+4} M_s$ ) finds its explanation under the framework of GTR due to irradiation of GWs.



These arguments might indeed look convincing if proof could be provided such that none of the existing alternative theories to GTR can furnish the capability to explain the LIGO detections. Without such a proof, an unambiguous conclusion with respect to the interpretation of the GW150914 signal in favor of GTR cannot, in general, be stated.

The goal of the present paper is to present a concise alternative explanation to the GW150914 signal, and to describe its principal characteristics under the framework of Yarman-Arik-Kholmetskii (YARK) theory of gravity [3].

An introductory framework of YARK theory has been drawn, e.g., in the papers [4-6]. Here, we present some principal points appertaining to our approach.

One main success of YARK theory was the fact that it provides a natural symbiosis between gravitation and quantum mechanics, as well as the elimination of any difficulties with respect to the definition of gravitational energy [7-9]. One can realize that the necessary condition for meeting the aforementioned criteria is the denial of a purely metric approach as had been applied in GTR and in extended theories of gravity.

It is known however that purely dynamic theories of gravity are incompatible with available experimental facts. These difficulties are overcome in YARK theory; which can be classified neither as a purely metric theory nor as a purely dynamic theory; it rather successfully combines the properties of both of them. In particular, in YARK, the force exerted on a test particle in the presence of gravity represents a non-vanishing entry in any frame of observation (just like in dynamic theories); at the same time, the origin of this force is explained via the variation of the metric of four-space, which makes YARK similar to metric theories in its many applications.

The combination of dynamic and metric properties is achieved via the principal postulate of YARK theory that defines the overall energy of an object moving in the presence of gravity as [4-9]

$$E = \gamma m_0 c^2 \left( 1 - E_B / m_0 c^2 \right), \quad (1)$$

where  $m_0$  is the rest mass of the object in the absence of gravity,  $\gamma$  is its Lorentz factor, and  $E_B$  the static binding energy of the object at the given location (*i.e.*, this is the energy delivered to the object at rest, in order to carry it quasi-statically to an infinity away).

In fact, eq. (1) states that the rest mass of the object is not of a constant value, but is rather altered in the gravitational environment by the value  $E_B/c^2$ .

Further, due to intrinsic quantum mechanical relationships between the quantities “mass”, “energy”, “frequency”, “time”, and “size”, the variation of the rest mass of a test particle by the static binding energy affects the internal time rate of the particle, and induces a conjoint transformation of spatial intervals in the presence of gravity [4-9]. Thus, the gravitational field alters the metric of space-time, so that the YARK expression for the space-time interval in the radially symmetric case reads as:

$$ds^2 = e^{-2\alpha} \left( c^2 t^2 - \frac{dr^2}{(1+\alpha)^2} - r^2 (d\theta^2 + d\varphi^2 \sin^2 \theta) \right), \quad (2)$$

where the factor  $\alpha = GM/rc^2$ ,  $G$  being the gravitational constant, and  $r$  being the distance from the center of the immobile host body  $M$  to the point of observation. Here the spherical coordinates  $r$ ,  $\theta$ ,  $\varphi$  are defined by the distant observer located outside of gravity.

Further, the action of a particle in YARK theory, defined in a usual way as  $S = -m_0 c \int ds$ , yields the energy of particle in the presence of gravity as [4-6]:

$$E = \gamma_0 m_0 e^{-\alpha} c^2, \quad (3)$$

so that, in comparison with the known expression for the energy of the particle in GTR [10],  $E_{GTR} = \gamma m_0 c^2 \sqrt{1 - 2\alpha}$ , the terms describing the effect of gravity in both theories coincide with each other to the accuracy  $c^{-3}$ . Therefore, GTR and YARK do converge in the limit of a weak gravitational field, and both provide a successful explanation of gravitational red shift, gravitational lensing, Shapiro delay and precession of the perihelion of Mercury [8,11,12].

It is worth emphasizing that YARK has attained exceptional milestones since the past few years in accounting for modern astrophysics and laboratory observations (e.g., derivation of the alternating sign for the accelerated expansion of the Universe without the need to invoke “dark energy”; presentation of the Hubble constant in an analytical form; elimination of the information paradox for black holes of the YARK type; a consistent explanation of the results of Mössbauer experiments in a rotating system [13-19]).

We emphasize that YARK, unlike GTR, remains fully compatible with quantum mechanics [9]. We accomplish this via following de Broglie, Vigier, and others [20-23], where we assume a finite rest mass for the photon, regardless of how far beyond the precision capabilities of modern measurement techniques it may lie [9]. We mention that the problem of gauge-invariance of classical electrodynamics with the massive photon can be successfully solved (see, e.g. [22,23]), though we omit here an analysis of this topic.

In the next section, we apply YARK to the analysis of the coalescence of two BHs, and explain all of the observed parameters of the GW150914 signal.

## 2. GW150914 signal in YARK theory

We use the following designations and values:  $R=1.2 \cdot 10^{25}$  m is the distance between the binary system and Earth,  $M_1=29M_s$ , and  $M_2=36M_s$  are the rest masses of orbiting BHs. Further we pose  $\eta=r_{max}/r_{min}$ , where  $r_{max}$  ( $r_{min}$ ) is the maximal (minimal) separation between BHs at each rotation period of their elliptic motion, and  $\omega$  is their angular rotational frequency.

One ought first to notice that the gravitational effect of two merging BHs on Earth is characterized via the variation of the quantity

$$\alpha[t] = G(M_1[t] + M_2[t])/Rc^2, \quad (4)$$

where we have taken into account that the inspiral motion of the bodies along elliptical orbits would entail the variation of their rest masses  $M_1$  and  $M_2$  with time in accordance with eq. (1). Here, the square bracketed item stands for the retarded time  $t \rightarrow t - R/c$ , supposing that gravitational perturbations propagate at the speed  $c$ .

The  $\alpha$ -factor (4), according to YARK, determines the lengths [8]

$$L = L_0 e^\alpha, \quad (5)$$

and the wavelength of light [8]

$$\lambda = \lambda_0 e^\alpha \quad (6)$$

under the influence of gravity, as assessed by the distant observer;  $L_0$  and  $\lambda_0$  are the corresponding quantities, measured in empty space.

The phase of the light beam passing the arm of the LIGO Michelson-Morley interferometer (MMI) and being reflected back is defined by the ratio

$$\varphi = 2L/\hat{\lambda} \quad (\text{where } \hat{\lambda} = \lambda/2\pi), \quad (7)$$

so that the phase (7) in YARK remains unchanged under quasi-static variation of gravity.

However, this is not the case for such a unique event as the merging of two BHs characterized by a rotational frequency up to 250 Hz. In the case of an elliptic inspiral motion of the progenitors, we can, for the time-dependent part  $|\Delta\alpha(t)|$  of the  $\alpha$ -factor, write:

$$|\Delta\alpha(t)| = A(t)\sin[\omega(t)t], \quad (8)$$

where the amplitude  $A(t)$  acquires the maximal value  $|\Delta\alpha|_{\max}$  at the rotational period preceding the merger event.

According to YARK, the variation of the spatial metric (5) induces the appearance of the corresponding effective force on the test masses, and the actual change of the lengths of the arms of the MMI in the dynamic situation is determined via the spatial displacement of the test masses, which is negligible at the resonant frequency of about 1 Hz.

Therefore, only the variation of the wavelength of the laser beam contributes to the shift of its phase (7) in the output of MMI. Hence, the phase of the light beam in the presence of the gravitational influence of the binary system is equal to

$$\varphi = \frac{2L_0}{\lambda_0 e^{\alpha(t)}} = \varphi_0 e^{-\alpha(t)}, \quad \frac{|\Delta\varphi|}{\varphi_0} \approx \Delta\alpha(t) \quad (\text{at } \Delta\alpha(t) \ll 1), \quad (9)$$

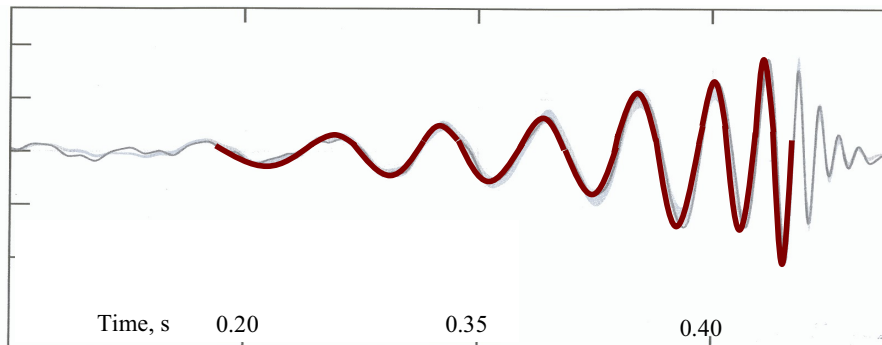
where  $\varphi_0 = 2L_0/\lambda_0$  is the light phase in the absence of gravity.

The corresponding numerical estimation yield the amplitude of the LIGO signal [3]

$$\left| \frac{\Delta\varphi}{\varphi_0} \right| \approx 3.4 \cdot 10^{-21} \frac{\eta - 1}{\eta}, \quad (10)$$

where we assumed an elliptical motion for the super-massive bodies in their revolution around each other with a minimal separation  $r_0$  and maximal separation  $\eta r_0$ , which corresponds to the observed value ( $\approx 1.1 \cdot 10^{-21}$ ) at  $\eta \approx 1.5$ .

At larger distances between the BHs, YARK predicts the  $1/r$  dependence of the amplitude of the detected signal, and the shape of the GW150914 signal calculated in YARK on the basis of eq. (8), is visibly indistinguishable from the shape of this signal calculated in ref. [1] on the basis of numerical estimations through GTR (see Fig. 1).



**Figure 1.** GW150914 signal (thin line) versus the result of its calculation in YARK theory (bold line) at the time range 0.30... 0.42 s [3].

As indicated in [24], YARK predicts that gravitational interaction between massive objects is to be accompanied by EM radiation even were they to remain electrically neutral. This kind of radiation emerges due to the variation of the rest masses of the objects as they get engaged in a gravitational environment [24]. Thus, when two BHs rotate around one another, they should each emit EM radiation, and the frequency of such a radiation coincides with their rotational frequency [24].

As shown in [14], the variation of the object's rest mass, in a stationary orbit, is exactly counterbalanced by the variation of the corresponding orbital kinetic energy of the object as seen by the remote observer. Therefore, the total energy of the released EM radiation  $E_R$  is equal to the kinetic energy of the progenitors just before the binary merger; *i.e.*,

$$E_R = (\gamma_1 - 1)M_1c^2 + (\gamma_2 - 1)M_2c^2, \quad (11)$$

and the difference between the rest masses of the progenitors and the daughter object is

$$\Delta M = E_R/c^2 = (\gamma_1 - 1)M_1 + (\gamma_2 - 1)M_2 \approx (\gamma - 1)(M_1 + M_2) \text{ (at } \gamma_1 \approx \gamma_2 \approx \gamma). \quad (12)$$

At  $\gamma=1.048$  ( $v \approx 0.3c$  [1]), eq. (12) yields  $\Delta M=3.1M_s$ , which practically coincides with the value  $3.0M_s$  presented in [1].

The energy (12) is to be released via EM radiation according to YARK, which has the proper frequency defined by the rotational frequency of the inspiralling entities (40... 250 Hz), and is further redshifted on Earth to the range 3... 20 Hz (we omit the corresponding calculations for brevity).

The estimated intensity of such radiation on Earth exceeds the threshold sensitivity of modern receivers; however, one should remind that the velocity of a massive photon is always less than  $c$ , and a given time lag must inevitably ensue between the GW150914 signal and the follow-up EM signal. For example, one can easily find that the time lag of two years is expected at the photon rest mass  $m_{op} \approx 4 \times 10^{-18}$  eV. It is expected to be equal to 15 years at  $m_{op} \approx 1.2 \times 10^{-17}$  eV, and near 150 years – at  $m_{op} \approx 3.9 \times 10^{-17}$  eV [3].

### 3. Conclusion

Henceforth, the “GW150914 event” and its principal characteristics can be adequately mimicked in YARK theory without any need to invoke GWs. At the moment, YARK remains the only theory, which provides its own explanation of the origin of the LIGO signal beyond the hypothesis about GWs and thus, it can be considered as the single and vital alternative to GTR. In these conditions, we find exciting that the recent experiments in space-time physics, in particular, the Mössbauer experiments in a rotating system [16-19] definitely support YARK, and remain non-explained in GTR. In addition, YARK is capable to provide a natural explanation with regards to the echoes [26] of the LIGO signal. It is that the BHs of YARK type (where they cannot be all the way “black” [16]) upon touch down, bounce back and forth, before their eventual coalescence. We thus have a picture of damped oscillations of the two BHs before an eternal rest.

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