The Detection of Gravitational Wave with the Laser Interferometer and Einstein's Theoretical Errors on Measurements

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Abstract

Because gravitational waves are very weak, the gigantic Laser Interferometer Gravity Wave Observatory (LIGO) with claimed sensitivity 10^{-22} represents the hope that gravitational waves would be observed directly in the near future. The theoretical foundation of LIGO's crucial design is Einstein's theory on measurement. However, it is found that Einstein's theory on measurement is actually incorrect both theoretically and experimentally. Theoretically, although gravity indeed makes the local distance changes, such change can be observed only in a free fall local space. Experimentally, the observed bending of light rays does not support Einstein's theory on measurement, but supports the existence of the Euclidean-like structure, which is unaffected by gravity. Nevertheless, these discoveries actually enhance general relativity since they clarify the physical meaning of coordinates. Thus, one has to conclude that LIGO would give null results and thus show that Einstein's theory on measurement is incorrect. Moreover, to show that Einstein's theory on measurement is invalid, there are much less expensive experiments. For instance, the experiments on local light speeds, pioneered by Zhou, would serve such a purpose since its theoretical foundation is the same as the assumption, which was used in the calculation of the bending of light rays, that the Euclidean-like structure will not be changed by gravity.

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Key Words: Einstein's Principle of Equivalence, Euclidean-like Structure, Einstein-Minkowski Condition.

1. Introduction

Since the observed behavior of binary pulsars has been interpreted successfully as due to gravitational radiation [1,2], the existence of gravitational wave is generally accepted. Moreover, theoretically the Maxwell Newton Approximation, [1)] which generates gravitational waves, has been established independent of the Einstein equation [3]. However, a direct observation of the gravitational waves has not been successful because a gravitational wave would be very weak in nature [4].

To obtain the required sensitivity of detection [5], two gigantic laser interferometer gravitational wave observatories (LIGO), among other great efforts, [2)] have been built, and currently they represent the hope of detecting the gravitational waves directly. The confidence on these new apparatus is based on the perceived high sensitivity [5] that is designed according to Einstein's theory on measurement [6,7]. Unfortunately, as will be shown, Einstein's theory on measurements is actually incorrect theoretically, and experimentally is in conflict with the observed bending of light. Nevertheless, this does not affect the validity of general relativity [8] since Einstein' theory on measurements is due to his oversight, but is not an integral part of general relativity.

In short, LIGO would fail to detect gravitational wave because, in spit of its very long arm length, its sensitivity would not be better than the existing laser interferometer. Therefore, Einstein's theory on measurement would be proven incorrect. Thus, we should start to think of a new way to measurement gravitational waves. In this paper, it will be shown first why Einstein's theory on measurement is incorrect, and then why his theory is in conflict with the observed bending of light.

2. Einstein's Theoretical errors on Measurements

In the initial development of Riemannian geometry, the metric was identified formally with the notion of distance in analogy as the case of the Euclidean space [9]. Such geometry is often illustrated with the surface of a sphere, a subspace embedded in a flat space [10]. Then, the distance is determined by the flat space and can be measured with a static method, i.e., attachment. For a general case, however, the issue of measurement was not addressed, before Einstein's theory.

In general relativity, the invariant line element in a physical space is

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu , \qquad (1)$$

where $g_{\mu\nu}$ is a space-time metric in a Riemannian space [6]. Since $g_{\mu\nu}$ is not a constant metric, one cannot hope to derive from (1) a simple distance formula as in Euclidean geometry where the spatial distance d (P_1, P_2) of two points P_1 and P_2 is still

$$d(P_1, P_2) = [(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2]^{1/2}. \qquad (2)$$

However, based on Einstein's equivalence principle, it is found [8] that the Euclidean-like structure [3)] with distance formula (2) must exist independent of the metric (1). For example, the Schwarzschild solution [4] of Riemannian space (x, y, z, t),

$$ds^2 = (1 - 2M\kappa/\rho)\, c^2dt^2 - (1 - 2M\kappa/\rho)^{-1}d\rho^2 - \rho^2 d\theta^2 - \rho^2 \sin^2\theta d\varphi^2, \tag{3}$$

where

$$\rho^2 = x^2 + y^2 + z^2, \qquad x = \rho \sin\theta \cos\varphi, \qquad y = \rho \sin\theta \sin\varphi, \qquad \text{and} \qquad z = \rho \cos\theta. \tag{4}$$

Here κ is a coupling constant, and M is the total mass. Then eq. (4) clarifies that the frame has a spherical coordinate system, and therefore has a Euclidean-like structure that satisfies the Pythagorean theorem.[4)] These space-time coordinates forms not just a mathematical coordinate system since a light speed ($ds^2 = 0$) is defined in terms of dx/dt, dy/dt, and dz/dt [7]. This illustrates that the Euclidean-like structure is included in Einstein's Riemannian space although this may not be a sufficient condition [11].

To understand the Euclidean-like structure, we must clarify what "measure" means to Einstein. In his theory, the measuring instruments are resting but in a free fall state that Einstein overlooked [6,7]. From Einstein's equivalence principle,[5)] time dilation and space contraction are obtained. Then, Einstein [7] claimed, "In the general theory of relativity, space and time cannot be defined in such a way that differences of the spatial coordinates can be directly measured by the unit measuring-rod, or differences in the time coordinates by a standard clock". Since Einstein considered the coordinates in terms of the metric, a problem of circular definition was created. Because of this, Whitehead [12] would not accept general relativity as a theory in physics.

However, if the measuring instruments are attached to the frame of reference, since the measuring instruments and the coordinates being measured are under the same influence of gravity, a Euclidean-like structure emerges as if gravity did not exist. From metric (3), it is clear that this operational defined Euclidean-like structure is a necessary complimentary structure of Einstein's physical space. In other words, *the physical meaning of space-time coordinates has already been provided in the theoretical framework of general relativity* [8]. Thus, the criticisms of Whitehead [12] are actually not valid for general relativity [8].

In general relativity, according to Landau and Lifshitz [13], the local distance *dl* is determined by

$$dl^2 = -\left[g_{\alpha\beta} - \frac{g_{0\alpha} g_{0\beta}}{g_{00}} \right] dx^\alpha dx^\beta, \quad \alpha, \beta = 1,2,3, \tag{5}$$

for

$$ds^2 = g_{00}(dx^0)^2 + 2g_{0\alpha} dx^0 dx^\alpha + g_{\alpha\beta} dx^\alpha dx^\beta$$

if the metric satisfies Pauli's version of the equivalence principle, that is, the metric has a proper signature. Thus [14],

$$ds^2 = g_{00}(dx')^2 + g'_{\alpha\beta}\, dx^\alpha dx^\beta = g_{00}\left[dx^0 + \frac{g_{0\alpha} dx^\alpha}{g_{00}} \right] + \left[g_{\alpha\beta} - \frac{g_{0\alpha} g_{0\beta}}{g_{00}} \right] dx^\alpha dx^\beta \tag{6a}$$

where

$$dx'^0 = dx^0 + \frac{g_{0\alpha} dx^\alpha}{g_{00}}, \quad g'_{\alpha\beta} = g_{\alpha\beta} - \frac{g_{0\alpha} g_{0\beta}}{g_{00}}. \tag{6b}$$

are respectively a new local time coordinate and new metric elements. Here dl represents the space contraction.

Obviously, the local distance formula (5) of Landau & Lifshitz makes no difference if $g_{\alpha 0} = 0$. However, this formula is crucial otherwise. For example, the metric for Einstein's rotating disk in the coordinate system K*(x', y', z', t) [13] is,

$$ds^2 = (c^2 - \Omega^2 r^2)\, dt^2 - 2\Omega r^2\, d\phi' dt - dr^2 - r^2\, d\phi'^2 - dz'^2 \tag{7a}$$

where

$$z = z', \quad x' = r\cos\phi', \quad \text{and} \quad y' = r\sin\phi'. \tag{7b}$$

Here K (x, y, z, t) is a Galilean (inertial) system of reference and the system K'(x', y', z') in a uniform rotation Ω relatively to K. We have $\phi = \phi' + \Omega t$, and (7b) manifests the Eucidean-like structure. Then, in the ϕ'-direction, one has the space contraction

$$(1 - \Omega^2 r^2/c^2)^{-1/2} r d\phi', \quad \text{and} \quad \oint ds = (1 - \Omega^2 r^2/c^2)^{-1/2} r' \int_0^{2\pi} d\phi' = 2\pi r'(1 - \Omega^2 r^2/c^2)^{-1/2} > 2\pi r' \tag{8}$$

i.e., the circumference of the circle with radius r' is larger as Einstein [6, 7] calimed. On the other hand, the "standard" arguments given by Ohanian and Ruffini [5; p. 164] is the following:

> "... and the spacetime interval becomes $ds^2 = g_{\mu\nu}\, dx^\mu dx^\nu$. This expression determines the spacestime distances. For example, a coordinate displacement dx^1 along the x-axis has a length $\sqrt{(-g_{11})}\, dx^1$, that is, the measured distance differs from dx^1 by a factor $\sqrt{(-g_{11})}$. Likewise, a coordinate time (t time) displacement dx^0 has a duration $\sqrt{g_{00}}\, dx^0$ when measured by the proper time of a clock at rest. "

Thus, one would have concluded that there is no space contraction from metric (7). However, some theorists would not accept the formula of Landau and Lifshitz [12] although they could not come up with a better solution. The reason of their rejection is that dx'^0 in (6b) is not integrable. Although Landau & Lifshitz [12] mentioned this characteristic, they consider the derivation of Landau & Lifshitz problematic. Now, the issue is whether the validity of (5) depends on (6b) is integrable.

On the other hand, the arguments of Landau & Lifshitz are not faultless because his implicit assumptions such as that the local frame is always physically realizable are only conditionally valid [14]. One may get the same result with the *Einstein-Minkowski condition* that the local space of a particle under gravity must be locally Minkowskian [6, 7]. However, for the case of a uniformly rotating disk, one may show explicitly from special relativity that the validity of formula (5) is independent of whether (6b) is integrable and dx'^0 would be just a local time.

Consider a particle P resting at (r', ϕ', z') of K*(r', ϕ', z', t). The local space of P is (dr', dX, dz', dT) which has a Minkowski metric. In K, P has a position (r, ϕ, z,) and its local space (dr, r$d\phi$, dz, dt) has the Minkowski metric in K. These two local spaces have a relative velocity $r\Omega$ in the ϕ–direction in K. Since r' = r, and z' = z, we have dr' = dr, and dz' = dz.

Then, the two local spaces relate to each other by the Lorentz transformation [7] in special relativity as follows:

$$dX = [1 - (r\Omega/c)^2]^{-1/2}\, [rd\phi - r\Omega dt], \tag{9a}$$

and

$$dT = [1 - (r\Omega/c)^2]^{-1/2}[dt - (r\Omega/c^2)\, rd\phi] \tag{9b}$$

From $\phi = \phi' + \Omega t$, one obtains

$$dX = [1 - (r\Omega/c)^2]^{-1/2}\, rd\phi' , \tag{10a}$$

and

$$dT = [1 - (r\Omega/c)^2]^{1/2}\, \{dt - [1 - (r\Omega/c)^2]^{-1}(r\Omega/c^2)\, rd\phi'\} \tag{10b}$$

Thus, the validity of formula (5) is independent of whether (6b) is integrable. Eq. (6b) is not integrable because dt' is related to different inertial systems at different r and t [15].

However, eq. (10a) shows that, *the local distance in the ϕ'-direction is measured from a local space at a free fall*, and therefore its is not measured in K'(x', y' z'). If the circumference of a circle in K' is measured, although the measuring rods are at rest, they must be in a different free fall state at each point, an impossible situation to execute. Thus, the local distance of Landau & Lifshitz [13] is not a distance in K' as they claimed, and thus formula (5) can be consistent with the Euclidean-like structure (7b).

Since the space contraction is measured in a free fall local space, this is a dynamic measurement. The measuring instrument is in a free fall state under the influence of gravity, while the Euclidean-like structure determines the static distance between two points in a frame of reference. Einstein's error is that he has mistaken this dynamic local measurement as a static measurement.

Consequently, Einstein and subsequent theorists believed that a space-time metric could be regarded as defining a locally measured distance as in the case of an embedded subspace [10]. This error probably arises from confusing mathematics and physics. This confusion is due to that the mathematically defined local distance would be measured physically only in a free fall local space in a different dynamic situation. Unfortunately, the crucial design of LIGO [5] is based on such a mistake.

3. Theoretical errors on Measurements and the Bending of Light

Moreover, there are experimental evidences against Einstein's theory on measurement. An example is the observed bending of light rays. Although the bending of light was first calculated with the Schwarzschild solution, here we would consider his later derivation [6] based on the Maxwell-Newton Approximation, [1)] which has been firmly established with Einstein's equivalence principle [3]. Currently, some theorists still incorrectly considered Einstein's equivalence Principle as non-essential [2]. However, this has been proven false again in this paper since the derivation of space contractions must rely on this principle.

Based on the Maxwell-Newton Approximation, the metric generated from the static massive energy-stress tensor $T(m)_{ab}$,

$$T(m)_{tt} = \sigma \quad \text{and} \quad T(m)_{ab} = 0 \text{ otherwise}, \tag{11a}$$

where σ is the mass density, Einstein obtained the static spacetime metric,

$$ds^2 = c^2 (1 - \frac{K}{4\pi}\int dV_0 \frac{\sigma}{R})dt^2 - (1 + \frac{K}{4\pi}\int dV_0 \frac{\sigma}{R})(dx^2 + dy^2 + dz^2), \tag{11b}$$

If Einstein's equivalence principle is valid (and so is the Einstein-Minkowski condition), for an observer P at point (x, y, z, t) with an arbitrary velocity v, under only the influence of gravity, there is a co-moving local Minkowski coordinate system (X, Y, Z, T) ,

$$ds^2 = c^2dT^2 - dX^2 - dY^2 - dZ^2. \tag{12}$$

For a spherical mass distribution σ, consider the case of v = 0, then for observer P one has

$$c^2dT^2 = c^2 (1 - \frac{K}{4\pi r}\int dV_0\sigma)dt^2 , \quad \text{where} \quad r = (x^2 + y^2 + z^2)^{1/2}; \tag{13a}$$

and thus

$$(dX^2 + dY^2 + dZ^2) = (1 + \frac{K}{4\pi r}\int dV_0\sigma)(dx^2 + dy^2 + dz^2). \tag{13b}$$

It follows from eq. (13a), the red shift for a frequency, which would have been ν_0 in a Minkowski space

$$\nu = \nu_0(g_{tt})^{1/2} = \nu_0(1 - \frac{K}{4\pi r}\int dV_0\sigma) \tag{14a}$$

and

$$L = \frac{d\ell}{dt} = c(1 - \frac{K}{4\pi r}\int dV_0\sigma) , \qquad \text{where} \qquad d\ell^2 = (dx^2 + dy^2 + dz^2), \tag{14b}$$

is the light speed of the space at (x, y, z, t). Currently, Einstein's 1911 preliminary application of the equivalence between acceleration and Newtonian uniform gravity was commonly but mistakenly regarded [8)] to be the same as Einstein's principle of equivalence [16]. Apparently, as Morrison [15] pointed out, they overlooked that the so calculated bending of light was incorrect.

If we imagine the sun, of mass M, concentrated at the origin of our system of coordinates, then a ray of light, traveling parallel to the x_3-axis, in the x_1-x_3 plane, at a distance Δ from the origin, will be deflected, in all by an amount [6,7]

$$\alpha = \int_{-\infty}^{+\infty} \frac{1}{L}\frac{\partial L}{\partial x_1}dx_3 = \frac{KM}{2\pi\Delta} \tag{14c}$$

where $M = \int \sigma dV_0$. Note that Δ is also measured "in the sense of Euclidean geometry [7]."

In fact, *all Einstein's predictions are in terms of the Euclidean-like structure.* The secular rotation of the elliptic orbit of the planet in the same sense as the revolution of the planet, amounting in radius per revolution to $24\pi^3a^2/(1 - e^2)c^2T^2$. In addition to Δ, *e* the numerical eccentricity and *a* the semi-major axis of the planetary orbit in centimeters are defined in terms of the Euclidean-like structure, and T the period of revolution in seconds is defined in terms of the time of a "quasi-Minkowskian space" [4].

Einstein stated that the light speed is measured "in the sense of Euclidean geometry [7]. " This confirms that the Euclidean-like structure decides the distance in a physical space, but not the local distance from the metric. In particular, the designer of LIGO should pay great attention because they had assumed incorrectly that the arm length of the interferometer is decided by the metric. According to the local distance of a metric, Liu [17] had defined a coordinate light speed as follows:

$$\frac{dl}{dt} = \varpi_{cor}(n^i) = \frac{c\sqrt{g_{00}}}{\gamma_i n^i + 1} \qquad \text{where} \qquad \gamma_i = -\frac{g_{0i}}{\sqrt{g_{00}}}, \tag{15}$$

and n^i is the directional vector. For an orthogonal metric, one has simply $\omega_{cor} = c(g_{00})^{1/2}$, which is essentially the invalid 1911 formula of Einstein, and the resulting bending is only one half of the observed. Thus, it is clear that the observed light bending supports that the distance is decided by the Euclidean-like structure instead of the metric.

4. Remarks

In current theory [5], to achieve maximum sensitivity, it is desirable to adjust the interferometer in such a way that in the absence of a gravitational wave, the light beams emerging from the two arms are out of phrase, $\phi = \pi$, and they interfere destructively. When a gravitational wave, then changes the length of one arm relative to the other by an amount x, the phrase between emerging light beams changes by an additional amount $\Delta\phi = 4\pi nx/\lambda$, where n is the number of back-and-forth reflections along such arm and λ is the wave length of the light. This $\Delta\phi$ was obtained with Einstein's theory of measurements.

At present, there are several groups using interferometric detection, of modest sensitivity, was built [5]. The first was by Forward & Moss in 1972; later more sensitive interferometric detectors were built by Billing (Munich), Drever (first at Glasgow, later at Caltech), Hough (Glasgow), and Weiss (MIT). All these interferometers, now in operation, have arm lengths of a few meters or a few tens of meters, and claimed to attain sensitivities of order $\kappa A \cong 10^{-19}$ (the minimum gravitational-wave amplitude, where $\kappa = (16\pi G/c^4)^{1/2} = 2.04 \times 10^{-24} s/(g\ cm)^{1/2}$) for gravitational waves of a frequency of about 1 kHz. However, none of these meters has succeeded in detecting any gravitational waves.

The crucial point of this design is the assumption that the arm length would change by the gravitational wave. However, the analysis shows that such change could be detected only locally in a free fall local space. In addition, the observed bending of light supports that the length of the arm of an interferometer would not be changed by gravity because the LIGO laboratory is built on the earth. Thus, Einstein's theory of measurement is not self-consistent and is in further disagreement with observation. One might argue that the mirrors are suspended only. However, this only means the mirror will be moved by a gravitational wave, and such a movement, which is independent of the arm length, has been proven as too weak to be detected. Therefore, one has no choice, but to conclude that LIGO, which claimed to have a sensitivity of the order of $\kappa A \cong 10^{-22}$ because the arm lengths would be several kilometers, would fail to observe gravitational wave and thus inadvertently confirms that Einstein's theory of measurement is incorrect.

In conclusion, the LIGO would give a null result to show that Einstein's theory of measurement is incorrect just as the Michelson-Morley experiment gives a null result that there is no absolute velocity. However, to show Einstein's theory on measurement is incor-

rect, there are much less expensive experiments. For instance, the experiment on local light speeds [8, 18] would serve such a purpose since its theoretical foundation is that the Euclidean-like structure in a frame of reference is not affected by gravity.

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Endnote

1) The Maxwell-Newton Approximation, whose sources are massive matter, could be identified as a special case of the so-called linearized approximation that has been found to be incompatible with Einstein equation for a dynamic situation [1, 2].
2) An interesting book [19] has been written on the great efforts to build LIGO.
3) So far as measurements are possible in principle, the Euclidean-like structure is operationally defined in terms of spatial measurements essentially the same as Einstein defined the frame of reference for special relativity [20]. Since the attached measuring instruments and the coordinates being measured are under the influence of the same gravity, a Euclidean-like structure emerges from such measurements as if gravity did not exist. However, such a coordinate system could be restricted due to considerations such as that the velocity of light in vacuum is the maximum of particle speeds.
4) An existence of the Euclidean-like structure (that Einstein [6, 7] called as "in the sense of Euclidean geometry") is necessary for a physical space [8]. The Euclidean-like structure is independent of the metric. For example, both the space with the Schwarzschild metric (3) and the space with the isotropic metric (11) have a frame with the Euclidean-like structure. Also, a local space at free fall usually has only a local Minkowski space at one point, but such a local space also has a frame with the Euclidean-like structure. Experimentally, such a structure has been verified by the bending of light (see Section 3).
5) Pauli's version of the principle of equivalence [21] was commonly but mistakenly regarded as Einstein's principle, although Einstein strongly objected to this version as a misinterpretation [22]. Moreover, there are other confusions. For instance, Misner, Thorne, & Wheeler [9; p. 386] falsely claimed that Einstein's equivalence principle is as follows:

   "In any and every local Lorentz frame, anywhere and anytime in the universe, all the (Nongravitational) laws of physics must take on their familiar special-relativistic form. Equivalently, there is no way, by experiments confined to infinitestimally small regions of spacetime, to distinguish one local Lorentz frame in one region of spacetime frame any other local Lorentz frame in the same or any other region. "

   However, this is only an alternative version of Pauli's because the Einstein-Minkowski condition, which requires that the local space in a free fall must have a local Lorentz frame, is missing.

6) A frame of reference is physical realizable if its coordinates are part of the coordinate system of a physical space, or equivalently physical measurements can be performed in such a frame.

7) For the Einstein-Minkowski condition, Einstein addressed only the diagonal metrics [6] or metrics without a crossing space-time element [7]. This creates a false impression that the Einstein-Minkowski condition is trivial. For instance, Synge [23], who is an excellent mathematician, failed to investigate the physics of Einstein's equivalence principle.

8) However, the meaning of Einstein's equivalence principle was commonly mistaken [24] to be the same as the preliminary application of equivalence with Newtonian gravity. This is fundamentally incorrect since the gravitation potential is a scalar in Newtonian theory, but is a second rank tensor in general relativity. A uniform gravity must be time-dependent because of Einstein's equivalence principle, but can be static in Newtonian theory.

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