International Journal of Advanced Research in Physical Science (IJARPS)
Volume 5, Issue 11, 2018, PP 31-42
ISSN No. (Online) 2349-7882
www.arcjournals.org

The Entanglement in Holographic CFTs- an Alternative Explanation of the Binary Black Hole Merger (LIGO) Experiment

Stefan Mehedinteanu

CITON — Center of Technology and Engineering for Nuclear Projects,Atomistilor no. 409, Bucharest-Magurele, Romania

***Corresponding Author:** ***Stefan Mehedinteanu**, CITON — Center of Technology and Engineering for Nuclear Projects,Atomistilor no. 409, Bucharest-Magurele, Romania*

Abstract: *During a merging process of two Black Holes (BH) it results a disruptive part as a new BH, that it could be supposed to generate inside stress-energy pulses infused in quantum and which spread by entanglement via bits threads till the timespace limit of LIGO site.*

Numerically it was demonstrated that only by using this model were obtained the measured parameters of LIGO experiment, mainly the pulse, that do not look as a gravitational wave especially at its end.

1. Introduction

Since, the **first observation of gravitational waves** 1 February 2016, when the signal was named **GW150914, and t**he event happened at the time $t = 1.4 billion\_ly \cong 4.4\times10^{16} \Leftrightarrow 1.32\times10^{25} m$, which is in range of earliest galaxies formation *~150 million(*$(4.7\times10^{15} s)$ *to 1 billion years* $(3.15\times10^{16} s \to 9.46\times10^{24} m)$ *after the Big Bang*, known as Reionization and 21 centimeter radiation epoch, for that we have considered the two primordial BHs as the nuclei of such galaxies and not originated from stars collapsing.

Recently the authors in [1], say that it was the first direct detection of gravitational waves , more exactly a pulse and the first observation of a frequency from 35 to 250 Hz with of strain of 1.0×10^{-21} of binary black hole merger (BHmg) with $3.0^{+0.5}_{-0.5} M_{SUN} c^2 \cong 5.3\times10^{47} J$ radiated in gravitational waves.

Also in [1], the gravitational waves (GW) observations constrain the Compton wavelength of the graviton to be $\lambda_g > 10^{16}[m]$, which could be interpreted as a bound on the graviton mass $m_g < 1.2\times10^{-22}\, eV/c^2 \cong 2.15\times10^{-58} kg$, and $\varepsilon_g = 1.9\times10^{-41} J$ ” , or $\hbar c/\lambda_g \cong 3\times10^{-42} J$ ”. These data were not confirmed in the present analysis, see below. The event happened at the time $t = 1.4 billion\_ly \cong 4.4\times10^{16} \Leftrightarrow 1.32\times10^{25} m$.

During the final 20 milliseconds of the merger, the power of the radiated gravitational waves peaked at about 3.6×10^{49} watts – 50 times greater than the combined power of all light radiated by all the stars in the observable universe.

2. The Bit Threads as the Nature of Hologram of LIGO Site

In the following will be shown how that one obtain some of these *measured* parameters only if we adopt the models of entanglement and not of gravitational waves!.

In the last time an important progress was done on the Ryu-Takayanagi (RT) formula generalization, especially by obtaining arguments about the nature of the transfer of bulk energy (Energy flux, the rate of transfer of energy through a unit area ($J\cdot m^{-2}\cdot s^{-1}$)) to the CFT horizon.

Thus, Bit threads provide an alternative description of holographic entanglement, replacing the Ryu-Takayanagi minimal surface with bulk curves connecting pairs of boundary points [2].

$$S_A = \frac{1}{4G_N} area(m(A))$$

Despite the fact that the RT formula has been a subject of intense research for over a decade, there are still many facets of it that are only now being discovered.

Indeed, only recently was it demonstrated that the geometric extremization problem underlying the RT formula can alternatively be interpreted as a flow extremization problem [3,4]. By utilizing the Riemannian version of the max flow-min cut theorem, it was shown that the maximum flux out of a boundary region A, optimized over all divergenceless bounded vector fields in the bulk, is precisely the area of m(A).

In particular, for the minimal surface m(A),

$$N_{A\bar{A}} \leq \frac{1}{4G_N} area(m(A)) \tag{1}$$

The number of threads connecting A to $\bar{A}$ is at least as large as the flux of v on A:

$$N_{A\bar{A}} \geq \int_A v$$

The reason that don't necessarily have equality is that some of the integral curves may go from $\bar{A}$ to A, thereby contributing negatively to the flux but positively to $N_{A\bar{A}}$.

Given (1), however, for a max flow v(A) this bound must be saturated:

$$N_{A\bar{A}} = \int_A v(A) = S(A)$$

The bit threads connecting A to $\bar{A}$ are vivid manifestations of the entanglement between A and $\bar{A}$, as quantified by the entropy S(A).

In [1] and therein ref. [3-7], the authors tried to reformulate the entanglement as a flux of vector field v.

In fact, theirs goal it was to explicitly construct the thread vector of Ref. [5], where the authors suggested replacing the minimal surface by a divergenceless vector.

The Ryu-Takayanagi (RT) formula relates the entanglement entropy of a region in a holographic theory to the area of a corresponding bulk minimal surface. Using the max flow-min cut principle, a theorem from network theory, in [5] they rewrite the RT formula in a way that does not make reference to the minimal surface. Instead, is invoked the notion of a “flow”, defined as a divergenceless norm-bounded vector field, or equivalently a set of Planck-thickness “bit threads”. The entanglement entropy of a boundary region is given by the maximum flux out of it of any flow, or equivalently the maximum number of bit threads that can emanate from it. The threads thus represent entanglement between points on the boundary, and naturally implement the holographic principle.

Instead, in [2] they will invoke the notion of a flow, defined as a divergenceless vector field in the bulk with pointwise bounded norm; note that this is a global object, not localized anywhere in the bulk. Its flow lines can be thought of as a set of “threads” with a cross-sectional area of 4Planck areas. In the picture below, each thread leaving the region A carries one independent bit of information about the microstate of A; S(A) is thus the maximum possible number of threads emanating from A. The equivalence of this formulation to equation (1) arises from the fact that the minimal surface acts as a bottleneck limiting the number of threads emanating from A; this is formalized by the so-called max-flow min-cut (MFMC) principle, a theorem originally from network theory but which they use here in its Riemannian geometry version

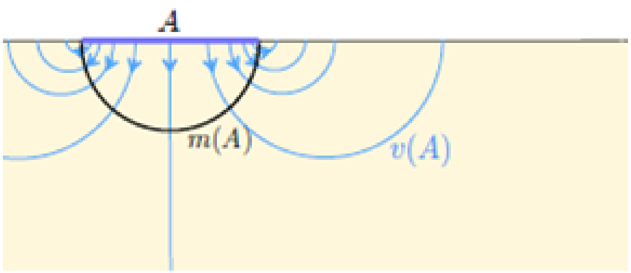

Figure 7 from [5]: According to eq. (1), the entanglement entropy of the region A is given by the maximum flux through A of any flow. A maximizing flow v(A) is illustrated by its flow lines in blue. This flux will equal the area of the RT minimal surface m(A) (divided by $4G_N$).

More about Bit Threads

As with an electric, magnetic, or fluid velocity field, it is convenient to visualize the flow v by its field lines. These are defined as a set of integral curves of v chosen so that their transverse density equals $|v|$. In [2] they call these flow lines "bit threads", for a reason that will become clear soon. Please keep in mind that the threads are oriented.

The bit threads inherit two important properties from the definition of a flow. First, the

bound $|v| = 1/4G_n$ means that they cannot be packed together more tightly than one per 4 Planck areas. Thus they have a microscopic but nonetheless finite thickness. In general, their density on macroscopic (i.e. AdS) scales will be of order N^2 (in the usual gauge/gravity terminology). Therefore, unless they are interested in 1=N effects (which will mostly ignore in this paper), it should not worry too much about the discrepancy between the continuous flow and the discrete threads. Second, the condition $\nabla \cdot v = 0$ means that the threads cannot begin, end, split, or join in the bulk; each thread can begin and end only on a boundary, which could be the conformal boundary where the field theory lives, or possibly a horizon (e.g. if are considering a single-sided black hole spacetime).

One of the most remarkable discoveries in fundamental physics was the realization that black hole horizons carry entropy. This entropy is manifest in the spacetime geometry, as expressed by the Bekenstein-Hawking formula:

$$S_{BH} = \frac{k_B c^3}{\hbar} \frac{A}{4G} \qquad (2)$$

where A is the area of the horizon.

Following [6a,b,c] of course, this expression (2) also reminds us that the physical constants in Nature can be combined to yield a fundamental length, the Planck scale:

$$l_P^{d-2} = 8\pi G\hbar / c^3$$

spacetime dimensions. Hence the geometric entropy (1) of the horizon is simply the horizon area measured in units of the Planck scale:

$$S_{geom} = 2\pi \frac{\mathrm{A}}{l_P^{d-2}}$$

Given a particular holographic framework, the entanglement entropy in the (d-1)-dimensional boundary theory between a spatial region A and its complement is calculated by extremizing the following expression

$$S(A) = \frac{2\pi}{l_P^{d-2}} \underset{v\sim A}{ext}\left[A(v)\right]$$

over (d-2)-dimensional surfaces v in the bulk spacetime which are homologous to the boundary region A.

In the following, we summarize here the main points of the derivation as given in Ref.[7]. Thus, the variation of the entanglement entropy obeys

$$\delta S_A = \delta \langle H_A \rangle \qquad (3)$$

Where H_A is the modular Hamiltonian.

However, starting from the vacuum state of a CFT in flat space and taking A to be a ball-shaped spatial region of radius R centered at x_0, denoted $B(R, x_0)$, the modular Hamiltonian is given by a simple integral that takes the simple form

$$H_B = 2\pi \int_{B(R,x_0)} d^{d-1}x \frac{R^2 - |\vec{x} - \vec{x}_0|^2}{2R} T_{tt}$$

of the energy density over the interior of the sphere (weighted by a certain spatial profile).

Thus, given any perturbation to the CFT vacuum that have for any ball-shaped region

$$\delta S_B = 2\pi \int_{B(R,x_0)} d^{d-1}x \frac{R^2 - |\vec{x} - \vec{x}_0|^2}{2R} \delta\langle T_{tt}\rangle$$

where H_B and S_B denote the modular Hamiltonian and the entanglement entropy for a ball, respectively.

One example is when is to consider a conformal field theory in its vacuum state, $\rho_{total} = |0\rangle\langle 0|$ in d-dimensional Minkowski space, and choose the region A to be a ball $B(R, x_0)$ of radius R on a time slice $t = t_0$ and centered at $x^i = x_0^i$.

Hamiltonian takes the simple form

$$H_B = 2\pi \int_{B(R,x_0)} d^{d-1}x \frac{R^2 - |\vec{x} - \vec{x}_0|^2}{2R} T_{tt}(t_0, \vec{x}) \tag{4}$$

where $T_{\mu\nu}$ is the stress tensor.

In summary, starting from the vacuum state of any conformal field theory and considering a ball-shaped region B, the first law (3) simplifies to

$$\delta S_B = \delta E_B \tag{5}$$

where is defined

$$E_B = 2\pi \int_{B(R,x_0)} d^{d-1}x \frac{R^2 - |\vec{x} - \vec{x}_0|^2}{2R} T_{tt}(t_0, \vec{x}) \tag{6}$$

The gravitational version of EB is simply obtained by replacing the stress tensor expectation value in (4) or (6) with the holographic stress tensor

$$E_B^{grav} = \int_S d\Sigma^{\mu} T_{\mu\nu}^{grav} \zeta_B^{\nu} = 2\pi \int_{B(R,\vec{x}_0)} d^{d-1}x \frac{R^2 - |\vec{x} - \vec{x}_0|^2}{2R} T_{tt}(t_0, \vec{x})$$

giving E_B^{grav} an integral of a local functional of the asymptotic metric over the region $B(R, x_0)$ at the AdS boundary.

To convert the nonlocal integral equations into a local equation, the strategy is to make use of the machinery used by Iyer and Wald to derive the first law from the equations of motion.

The Iyer-Wald formalism is reviewed in detail in the next section, but for now is just need one fact: the crucial step in the derivation is the construction of a (d−1)-form χ that satisfies

$$\int_B \chi = \delta E_B^{grav}, \int_B \chi = \delta S_B^{grav} \tag{7}$$

and for which $d\chi = 0$ on shell (i.e. when the gravitational equations of motion are satisfied).

The first law follows immediately by writing $\int_\Sigma d\chi = 0$ and applying Stokes theorem (i.e. integrating by parts).

To derive local equations from the gravitational first law, they show that there exists a form χ which satisfies the relations (7) off shell, and whose derivative is

$$d\chi = -2\xi_B^a \delta E_{ab}^g \varepsilon^b \tag{8}$$

where the d-form ε^b is the natural volume form on co-dimension one surfaces in the bulk (defined in eq. (5.3) from [7]), ξ_B is the Killing vector that vanishes on $\widetilde{B}(R, x_0)$, and δE_{ab}^g are the linearized gravitational equations of motion. In addition, they require that

$$d\chi|_{\partial M} = 0 \tag{9}$$

where ∂M is the AdS boundary, assuming the tracelessness and conservation of the holographic stress tensor.

In detail in [7], by using the Noether identity (discussed in appendix B of [7]) linearized about the AdS background is obtained.

$$\nabla_a (\delta E^g)^{ab} = 0, \tag{10}$$

a divergenceless condition as the necessity mentioned before.

Using the vanishing of $E_{\mu\nu}^g$, the general solution to (10) can be written as:

$$\delta E_{z\mu}^g = z^{d-1} C_\mu, \ \delta E_{zz}^g = z^{d-2} C_z - \frac{1}{2} z^d \partial_\mu C^\mu \tag{11}$$

for unfixed C_μ, C_z which are functions of the boundary coordinates. It simply need to show that C_μ, C_z must vanish. This is achieved by the requirement (9) which (using eq. (8) and (11) gives:

$$0 = d\chi|_{\partial M} = -\left(\zeta_B^\mu C_\mu + \widetilde{\zeta}_B^x C_z\right) dt \wedge dx^1 ... \wedge dx^{d-1} \tag{12}$$

Here, is defined $\widetilde{\zeta}_B^z = \lim_{z \to 0} (z^{-1} \zeta_B^z) = -2\pi R^{-1}(t - t_0)$ which is related to the boundary conformal Killing vector via: $\partial_\mu (\zeta_B)_\nu + \partial_\nu (\zeta_B)_\mu = 2\eta_{\mu\nu} \widetilde{\zeta}_B^z$. Since it is possible to construct _ for all possible boundary regions B and in all Lorentz frames, it follows that $C_\mu = C_z = 0$.

In summary, it can obtain the full set of linearized gravitational equations, if it can

show that a form χ exists, which satisfies eqs. (7), (8) and (9), they in [7] found this. Thus, applying this discussion in an arbitrary frame, after a long way they have now established that, at the boundary, χ is equal to the conserved current that appears in the modular energy:

$$d\chi|_{\partial M} = d \sum^\mu T_{\mu\nu}^{grav} \zeta^\nu \tag{13}$$

Conservation and traceless of the CFT stress tensor therefore imply $d\chi|_{\partial M} = 0$, completing the derivation requested.

Now, only the differential form for Gauss's law for magnetism is of this type:

$$\nabla \cdot B = 0$$

The magnetic field **B**, like any vector field, can be depicted via field lines (also called *flux lines*) – that is, a set of curves whose direction corresponds to the direction of **B**, and whose areal density is proportional to the magnitude of **B**. Gauss's law for magnetism is equivalent to the statement that the field lines have neither a beginning nor an end: Each one either forms a closed loop, winds around forever without ever quite joining back up to itself exactly, or extends to infinity.

3. MAGNETIC FIELD GENERATION IN FIRST ORDER PHASE TRANSITION BUBBLE COLLISIONS

To note, that in case of electroweak and QGP epochs the magnetogenesis is analyzed for different mechanisms [8], [9], [10], [11], [3], [12].

We can now wonder what is the strength of the magnetic fields at the end of the EWPT. A partial answer to this question has been recently given in [11] where the formation of ring-like magnetic fields in collisions of bubbles of broken phase in an abelian Higgs model were inspected.

Under the assumption that magnetic fields are generated by a process that resembles the Kibble and Vilenkin [13] mechanism, when W condensate- and Z strings-configurations are expected to form, it was concluded that a magnetic field is of the order $B = 2\times10^{20} G \cong 2\times10^{16}[T]$.

Assuming turbulent enhancement of the field by inverse cascade, a root-mean-square value of the magnetic field $B_{rms} = 10^{-21} G \cong 10^{-17}[T]$ on a commoving scale of $10Mpc \cong 3\times10^{23}[m]$ as from [11].

In the case of a first order electroweak (EW) phase transition, the Higgs field inside a given bubble has an arbitrary phase [11]. The bubbles expand and eventually collide, while new bubbles are continuously formed, until the phase transition is completed. This also involves the equilibration of the phases of the complex Higgs fields, the gradients

of which act as a source for gauge fields, thus making the generations of magnetic fields possible. The magnetic field generated in bubble collisions will be imprinted on the background plasma.

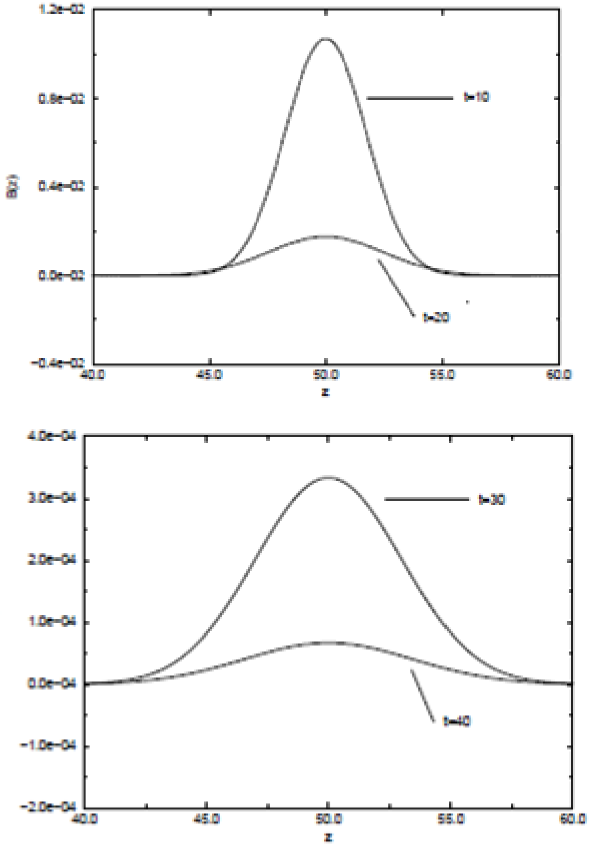

Figure 5 from [11]: B with v = 1, r = 1, σ = 7, R = 10 and t = 10, 20, 30 and 40 after the initial collision. The point of initial collision on the z-axis is $z_1 = 50$ (and units are $e\eta = 1$; the gauge boson mass $m_A = e\eta = T_c$).

It is convenient to write the Higgs field in polar form:

$\Phi = \frac{1}{\sqrt{2}} X e^{i\theta}$; X settles rapidly to its equilibrium value η.

Again the magnetic field escapes from the intersection region and moves outwards with the speed of light.

4. Building up Spacetime with Quantum Entanglement

These are obtained by using well-known Inflation models [14a-c], (which in our opinion is nothing else than a spreading of entanglement-energy source-horizon end), where the scale leaving the horizon at a given epoch is directly related to the number $N(\varphi)$ of e-folds of slow-roll inflation that occur after the epoch of horizon exit. Indeed, since H -the Hubble length is slowly varying, we have $d\ln k = d(\ln(aH)) \cong d\ln a = \frac{\dot{a}dt}{a} = Hdt$. From the definition this gives $d\ln k = -dN(\varphi)$, and therefore $\ln(k_{end}/k) = N(\varphi)$, or, $k_{end} = ke^{N}[m]$, where k_{end} is the scale leaving the horizon at the end of slow-roll inflation, or usually $k^{-1} << k_{end}^{-1}[m]$, the correct equation being $k = k_{end}e^{N}[m^{-1}]$.

That results for a resulted Black-Holes merging (BHmg) are $a \cong R = H^{-1} = r_{object} \cong r_{Sck}$.

where $\rho = \frac{r_{Sck}c^{2}}{Gr_{Oject}^{3}}$,

with directly $r_{Sch} = \frac{2GM_{U}}{c^{2}}$.

Finally, we have the above RT formula as expressed in the bit threads:

$$\frac{2\pi}{\hbar}\int d^{2}x\sqrt{g}T_{\mu}^{\mu} = \frac{2\pi}{\hbar}\rho_{bulk} = \frac{3H^{2}}{2\cdot 2\cdot G}n\frac{1}{\hbar} \tag{25}$$

$$\frac{2\pi\cdot c^{3}\cdot\rho}{\hbar} = \frac{3H^{2}\cdot c^{3}}{4G}\frac{1}{\hbar} \quad \text{or} \quad \frac{c^{3}\cdot\rho}{3\hbar} = \frac{H^{2}\cdot c^{3}}{8\pi G}\frac{1}{\hbar} \quad \text{or,} \quad \frac{c^{3}\cdot\rho\cdot l_{P}^{2}}{3\hbar} = H^{2}[s^{-2}], \quad \text{or,} \quad \frac{c^{3}\cdot\rho\cdot l_{P}^{2}}{3\hbar}\frac{1}{c^{2}} = H^{2}[m^{-2}] \tag{26}$$

$$\rho\big|_{bulk} = n_{bit\_threads}\rho_{bubble} = n\rho = n\frac{T_{j}}{c^{2}\lambda_{C}^{3}}$$

For example, with data for the LIGO site we have, see below: $\rho = \frac{M_{U}}{n_{bit\_threads}\cdot\lambda_{C}^{3}} = 400[kg/m^{3}]$ (26')

$n = n_{bit\_threads} = \frac{M_{U}c^{2}}{m_{A}} = 3\times 10^{74}$; from section 3. above, we appreciate

$m_{A} = 6\div 10GeV \rightarrow 1.7\times 10^{-8}[J]$; $l_{P} = 7.8\times 10^{-35}$, that results from eq. (26) $H = 3.5\times 10^{24}[m]$

In the case of a homogeneous potential directed along the z-axis [8] eq. (2.2), the Einstein stress-energy tensor is:

$T^{00} = T^{11} = T^{22} = -T^{33} = \rho = \frac{\varepsilon_{0}c^{2}B^{2}}{8\pi}$; $T^{0i} = 0$, where $\rho_{B}[J/m^{3}]$-the magnetic energy density.

$$\varepsilon = \frac{V_{vol}\varepsilon_{0}c^{2}B^{2}}{8\pi} = \rho V_{vol} = V[J],$$

$V_{vol} = 2\pi\lambda_{C}\lambda_{c}(4\lambda_{C}) \cong 8\pi\lambda_{C}^{3}$, at Compton length equally with the penetration length $\lambda_{C} = \lambda$, that results

$$E^{2} = \frac{(V)}{\varepsilon_{0}(\lambda_{C}^{e*})^{3}}$$

With $V = \varepsilon_{gluons}$ as above is obtained $B = E_{q\bar{q}}/c$.

$$\varepsilon = \frac{V_{vol}\varepsilon_0 c^2 B^2}{8\pi} = \rho_B V_{vol} = V = m_A = [J], \qquad (27)$$

$V_{vol} = 2\pi\lambda_C\lambda_c(4\lambda_C) \cong 8\pi\lambda_C^3$, at Compton length $\lambda_C = \hbar/mc$

$$E^2 = \frac{(V)}{\varepsilon_0(\lambda_C^{e*})^3} \text{ , also } E = Bc = \frac{\hbar c}{e\lambda_C^2}$$

Here, the Hubble constant is defined as, see eq. (3.20,3.21,3.22) from [8].

$$H^2 = \frac{8\pi G V^4}{3(\hbar c)^3 c^4} \; [m^{-2}], \quad \text{and by use of the Compton length as:}$$

$$H^2 = \frac{1}{R^2} = \frac{8\pi G V^4}{3(\hbar c)^3 c^4} \to \frac{8\pi G V^4}{3\lambda_C^3 (mc^2)^3 c^4} \to \frac{8\pi G}{3}\frac{V}{\lambda_C^3 c^4}[m^{-2}] \qquad (27')$$

Strain Model

From [15] we have:

$$\lambda = \kappa^{-1}e^{kv};\ \kappa^{-1} = 4M;\ v = t + r^*;\ C = 1 - 2M/r;\ \text{and } r^* = \int C^{-1}dr;\ C_{,r} = 2M/r^2$$

We will assume that $T_{vv}(v)$ represents ingoing/outgoing radiation which changes the black hole's mass by only a small fractional amount, $|\Delta M| << M$. We can then take κ to be constant to lowest order. If we change the independent variable from λ to v = t + r∗, then

$$\frac{d}{d\lambda} = e^{-\kappa v}\frac{d}{dv};\ v = 1/\omega;\kappa = \frac{c^3}{4GM}$$

And

$$T_{\mu\nu}k^\mu k^\nu = e^{-2\kappa v}T_{vv}$$

For spherically symmetric pulses, the shear and vorticity vanish, and the Raychaudhuri equation, Eq. (36) from [15], becomes

$$\frac{d\theta}{dv} = -\frac{1}{2}e^{\kappa v}\theta^2 - 8\pi e^{-\kappa v}T_{vv}(v)$$

The equation for the horizon area can be expressed as

$$\frac{dA}{dv} = e^{\kappa v}A\theta$$

If we take $A_0 = 16M_0^2$ to be the initial area of the black hole in the distant past, where M_0 is its initial mass, then we have

$$\frac{\Delta A}{A_0} \cong \frac{a}{\kappa}e^{\kappa v_+} = 2\frac{\Delta M}{M_0}$$

In this approximation, the change in the mass of the black hole is

$$\Delta M = \frac{a}{2\kappa}M_0 e^{\kappa v_+} = \frac{aA_0}{8\pi}e^{\kappa v}$$

where we have used $\kappa = 1/(4M) \cong 1/(4M_0)$.

This agrees with the result obtained by calculating the change in mass directly from Eq. (29) as $\dot{M} = \frac{dM}{dt} = F = \int T_t^r r^2 d\Omega$

On the horizon, $T_t^r = T_{vv}$, $r = 2M + \varepsilon$

Since the quarks generated inside nucleons or in EW bubbles are generated by a pulsating process with frequency $\nu = \omega^{-1}$, a such pulse of stress-energy it could be $8\pi T_{\mu\nu} k^\mu k^\nu = a\delta(\lambda)$, a is a positive constant, and the surface gravity $\kappa = \frac{c^3}{GM}[s^{-1}]$.

We can observe that $\frac{\Delta A}{A} = \frac{8\pi GM}{c^2} \cdot \frac{1}{R} = \frac{r_{Schw}}{R}$, or, we have obtained the classical formula for deformation.

The Born of Quarks Inside the Nucleons as a Permanent Process

Now, the rate per unit volume of quarks pair creation is given by using the Schwinger effect R inside the nucleon or EW bubbles, *when this electric field* E *is induced by* $e^+ - e^-$ *quarks pairs which decay in* $W^{\pm}$ *that explaining* β^- *decay,* of leading order behavior

$$R = (E/E_{cr})^2 (c/\lambda^4)(8\pi^3)^{-1} * \exp(-\pi E_{cr}/E) \tag{28}$$

or $E/E_{cr} << 1$, positron charge e, mass m, Compton wave-length $\lambda_C = \hbar/mc$ and so-called "critical" electric field

$$E_{cr} = m^2 c^3 / e\hbar$$

the volume is given by:

$V_{matter} = (\lambda_C)^4 \frac{1}{c}[m^3 s]$; the mass of quarks.

4.1. The Formation of the Disruptive BH Due of the Binary Merging (LIGO)

The resulting disruptive BH of the BHs binary, as being only ~2% of the cumulative masses [1], or $3 \times M_{SUN} = 5.3 \times 10^{47} J$, and with $\varepsilon_{mgBH} = 10/a_{end\_mgBH} = 5.4GeV = 8.6 \times 10^{-10} J$,

$m_A = 6 \div 10GeV \rightarrow B_{magnetic\_flux=} = 1.9 \times 10^{16}[T] \rightarrow 2 \times 10^{20} G$ as in section 3. and eq. (27), the horizon-entry is when $k_{end} = k_{leave} e^{-N}$; $k_{end}^{-1} = 2330[m]$, $a_{end\_mgBH} = 1.85$, and with eq. (26), $H_{end}^{-1} = 6055[m]$, and respectively, from eq. (26') with $\rho = 2.3 \times 10^{23}[kg/m^3]$ $n = n_{hologram} = 6 \times 10^{56}; r_{object} \approx r_{Sch}$, $t_{end} = H_{end}^{-1}/c \cong R/c = 1.4 \times 10^{-5} s$, where with $H_{leave}^{-1} = k_{laeve}^{-1} = 10^{-18}[m]$ we found $N = 49.2$ to match the iterations cycle: $m_g \rightarrow \hbar\nu \rightarrow k_B T \rightarrow \varepsilon \rightarrow R \rightarrow H_{end}^{-1} \rightarrow a_{end} \rightarrow N$.

$\lambda_{C\_mgBH} = 3.4 \times 10^{-17}[m]$, $\upsilon = c/k_{end}^{-1} = 1.2 \times 10^5 Hz$, thus, the curvature radius R is equally with Schwarzschild radius.

The strain at BHmg CFT

We use the above strain model of section (4)

With $a = \frac{c}{R}[s^{-1}]$; where from eq. (26) $R = r_{Schw} = 6055[m]$; $a = 4.9 \times 10^4$; with $M = 5.9 \times 10^{30}[kg]$; $\kappa = 1.68 \times 10^4 [s^{-1}]$; if we have the generation with eq. (28)

$v=\omega^{-1}=(R/V\cdot V_{vol})^{-1}$; where $R/V\times V_{vol}\cong 3\times 10^{66}\cdot\lambda_C^3=1.2\times 10^{17}[s^{-1}]$, $v=8\times 10^{-18}[s]$; $e^{\kappa v}\cong 1.000$

So, the deformation is $\frac{\Delta A}{A}=2.9$ an important initially distortion.

We can observe that $\frac{\Delta A}{A}=\frac{8\pi GM}{c^2}\cdot\frac{1}{R}=\frac{r_{Schw}}{R}=1$, or, we have obtained the classical formula for deformation.

4.2. The Entanglement in Case of LIGO Experiment

Therefore, the new horizon of EWPT bubbles collisions, where the stress-energy pulse leaves under the form of bit threads, see figure 1., $a_{leave}=k_{leave}/H_{leave}=1$, or $k_{leave}^{-1}=H_{leave}^{-1}=r_{Schw}$.

Now, the new horizon-entry-LIGO detector is when the wave length $k_{end}=k_{leave}e^{-N}$; $k_{end}^{-1}=2.3\times 10^{13}[m]$; and the scale factor arrives at $a_{end}=k_{end}/H_{end}$, the Hubble length with Compton length $\lambda_C^{LIGO\_site}=\hbar/m_{g\_GW}c=10^{-5}[m]$; the disruptive mass $M_U=5.94\times 10^{30}kg$; $a_{end\_mgBH}=5.6\times 10^{11}$ and with eq. (26), $H_{end}^{-1}=3\times 10^{26}[m]$, when the number of bit threads passing through hologram and attaining the LIGO-site is $n_{LIGO-site}=n_{bit\_threads}=\frac{M_U c^2}{m_A\cdot a_{end\_mgBG}}=10^{45}$ from the total at hologram of $\cong 6\times 10^{56}$ and from eq. (26') results $\rho=4.65[kg/m^3]$, with data for the LIGO site we have: $\varepsilon_{mgBH}=10/a_{end\_mgBH}=1.7\times 10^{-11}GeV=2.8\times 10^{-21}J$; the commoving magnetic flux is

$B_{magnetic\_flux=}=2\times 10^{-7}[T]\to 5\times 10^{-11}G$, as in section 3. and eq. (27),

$t_{end}=H_{end}^{-1}/c=4.3\times 10^{16}s$, we found $N=21.7$ to match the iterations cycle: $m_g\to\hbar v\to k_BT\to\varepsilon\to R\to H_{end}^{-1}\to a_{end}\to N$.

In order to identify $e\eta$ in [11], and in figure 5., we proceed as following. We know that for $v=247GeV\to\lambda_L^2=\left(4\pi\alpha v^2/(\hbar c)^2\right)^{-1}\cong 5.5e-36m^2$, or $\lambda_L\cong 2.3e-18[m]$, which is the Compton length for $W^{\pm}$ bosons [16]. Thus, we have add one constraint equation to the four Klein-Gordon equations; the only linear, Lorentz invariant choice is

$(\Diamond+m^2)A_\mu(x)=0$ and $\partial_\mu A^\mu=0$. $\Diamond=\left(\frac{\partial^2}{\partial t^2}-\nabla^2\right)$ is the d'Alembertian. For the time-independent case, the Klein–Gordon equation becomes

$\left[\nabla^2-\frac{m^2c^2}{\hbar^2}\right]\psi(r)=0$; where $\frac{m^2c^2}{\hbar^2}\Leftrightarrow[m^{-2}]$

It then follows that a Klein-Gordon equation holds for A, from [11]

$$(\partial_\mu\partial^\mu+e^2\eta^2)X=0,\ \text{where}\ X=A_\mu$$

Introducing $\alpha^{-1}=\frac{4\pi\varepsilon_0\hbar c}{e^2}=137$ in λ_L is obtained $\lambda_L^2="e^2\eta^2"=\left(\frac{e^2v^2}{\varepsilon_0(\hbar c)^3}\right)^{-1}$

Therefore, in figure .7 results at the hologram site $"e\eta"=1.5\times 10^{15}[m^{-1}]$; so $50/1.5\times 10^{15}=3.2\times 10^{-14}[m]$ when $v=m_A=1.5\times 10^{-10}[J]$, and respectively, at LIGO site, since the number of bit threads from initially value of 5.6×10^{56} it pass only $\cong10^{45}$, and with $m_A = 2.8\times10^{-21}[J]$ as above, in the formula above we have for $v = m_A \cdot \frac{10^{45}}{6\times10^{56}} = 5.1\times10^{-33}[J]$ $"e\eta" = 5.3\times10^{-8}[m^{-1}]$; so, the pulse dimension from figure 5., it is $\cong 50*5.3\times10^{-8} = 2.6\times10^{-6}[m^{-1}]$, so the frequency is $\omega = c\cdot"e\eta" = c*5.3\times10^{-8} = 15Hz$, which is exactly the frequency measured in [1].

The strain at LIGO site

We use the same above model of section (4)

With $a = \frac{c}{R}[s^{-1}]$; where $R = 1.2\times10^{25}[m]$; $a = 8.4\times10^{-17}$; with $M = 5.9\times10^{30}[kg]$; $\kappa = 1.6\times10^{4}[s^{-1}]$; if we keep the same generation as in section above for the BH based on eq. (26) , $v = 8\times10^{-18}[s]$; $e^{\kappa v} \cong 1.0008$.

In other words the pulse is entangled at LIGO site.

So, the deformation is $\frac{\Delta A}{A} = 4.9\times10^{-21}$ as in LIGO measurement, see figure 1.

Separately, with the LIGO site curvature radius as

$R_{LIGO} = 1.3\times10^{9}\,Light\_years\times c = 1.25\times10^{25}m$,

and if we will use for classical comparison, the Schwarzschild radius

$r_{Schw} = \frac{2G\cdot3M_{SUN}}{c^2} = 8.7\times10^{3}[m]$, we have

$$\frac{r_{Schw}^2}{R_{LIGO}^2} = \frac{(8.7\times10^3)^2}{(1.25\times10^{25})^2} = 5\times10^{-43} \rightarrow \theta = r_{Schw}/R_{LIGO} = 7.2\times10^{-22}$$

so, in both cases at (LIGO laser site) the strain is around $\theta = r_{Schw}/R \cong 1.1\times10^{-21}$, that is near equally with the experimental strain $\cong10^{-21}$ given in [1].

To note the value of the magnetic flux at LIGO site as given by

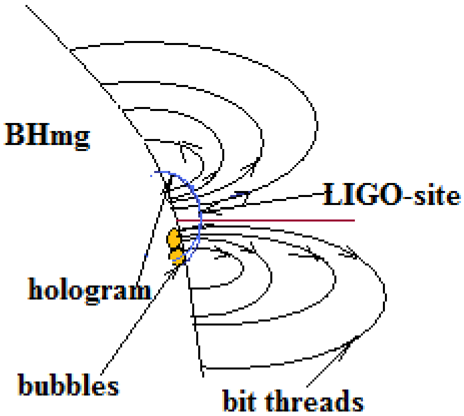

Figure1. *The entanglement between BH-merger and LIGO-hologram*

$$B_{LIGo\_site} = \frac{B_{mgBHs}}{a_{end\_LIGO\_site}^2} = \frac{1.9\times10^{16}}{(1.1\times10^{18})^2} = 1.4\times10^{-20}[T]$$

5. Conclusions

By adopting a model of entanglement of the stress-energy pulse as a magnetic field of fluxoid type after bubbles collisions of two mergered black-holes which generate the bit threads (flux lines) infused in vacuum, and thus, it is created a hologram at LIGO site. By using this model are confirmed the pulse and the frequency from 35 to 250 Hz with the strain of 1.0×10^{-21}. All these were with the new discovered Ryu-Takayanagi (RT) formula. Therefore, the numerical results can sustain this model.

References

[1] B. P. Abbott et al., Observation of Gravitational Waves from a Binary Black Hole Merger, PRL 116, 061102 (2016) Selected for a Viewpoint in Physics PHYSICAL REVIEW LETTERS, 12 FEBRUARY

[2] Shawn X. Cui, et al., Bit Threads and Holographic Monogamy, arxiv:1808.05234v1 [hep-th], 2018.

[3] T. Faulkner, F.M. Haehl, E. Hijano, O. Parrikar, C.Rabideau, and M. Van Raamsdonk, Nonlinear gravity from entanglement in conformal field theories, J. High EnergyPhys. 08 (2017) 057.

[4] Matthew Headrick, Veronika E. Hubeny, Riemannian and Lorentzian flow-cut theorem, arxiv:1710.09516v1, 2017.

[5] M. Freedman and M. Headrick, Bit threads and holographic entanglement, Commun. Math. Phys. 352, 407 (2017).

[6] a) Eugenio Bianchi, Robert C. Myers, On the Architecture of Spacetime Geometry, arxiv:1212.5183v1 [hep-th], 2012, b) Eugenio Bianchi, Black hole entropy from graviton entanglement, arxiv:1211.0522v2 [gr-qc], 2013. c) Eugenio Bianchi, Black hole entropy from graviton entanglement, arxiv:1211.0522v2 [gr-qc], 2013.

[7] T. Faulkner, M. Guica, T. Hartman, R. C. Myers, and M. Van Raamsdonk, Gravitation from entanglement in holographic CFTs, J. High Energy Phys. 03 (2014) 051.

[8] Dario Grasso, Hector R. Rubinstein, Potentials in the Early Universe, arxiv:astro-ph/0009061v2, 2001

[9] T. Vachaspati, Phys. Lett. B265 (1991) 258.

[10] Dario Grasso, Antonio Riotto, On the Nature of the Magnetic Fields Generated During the Electroweak Phase Transition, arxiv:hep-ph/9707265v2, 1997.

[11] J. Ahonen and K. Enqvist, Magnetic field generation in first order phase transition bubble collisions, hep-ph/9704334, 1997.

[12] L.S. Kisslinger, hep-ph/0202159

[13] W.B. Kibble and A. Vilenkin, Phys. Rev. D52 (1995) 679.

[14] a) A. H. Guth and S. Y. Pi, Phys. Rev. Lett. 49 (1982) 1110; b) ALAN H. GUTH, Inflation, arxiv:astro-ph/0404546v1 27Apr 2004; c) Andrew R. Liddle, David H. Lyth, The Cold Dark Matter Density Perturbation arXiv:astr-ph/930.3019v1,1993.

[15] L.H. Ford, Thomas A. Roman, CLASSICAL SCALAR FIELDS AND THE GENERALIZED SECOND LAW, arXiv:gr-qc/0009076v2, 2001.

[16] Stefan Mehedinteanu, On the Acceleration of Beta Nuclides Decay by the Photonuclear Reaction, International Journal of Nuclear Energy Science and Engineering (IJNESE) Volume 2, Issue 2 2012 PP. 45-56 www.ijnese.org © World Academic Publishing

Citation: *Stefan Mehedinteanu. "The Entanglement in Holographic CFTs- an Alternative Explanation of the Binary Black Hole Merger (LIGO) Experiment", International Journal of Advanced Research in Physical Science (IJARPS), vol. 5, no. 11, pp. 31-42, 2018.*