Article

On the Three Findings by LIGO

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Abstract

During the last year, LIGO collaboration has made three important discoveries suggesting the possibility of new physics. Gravitational waves were detected from what was identified as a merging of blackholes at distance of 3 billion lightyears. What looks mysterious is the high mass of the colliding objects. Same is true also for the earlier collisions. This raises the question whether the nuclear physics inside the stars is really understood. The observation of GW170817 was a further important event, perhaps *the* event of the year in physics. Both gravitational waves and electromagnetic radiation from the collision of two neutron stars fusing to single object were detected. The finding eliminated a class of models claiming that dark matter and energy do not exist. The third news was that LIGO had found no support for gravitational radiation from cosmic strings predicted by GUTs and by superstring models, which typically assume GUT type theory as a long length scale limit. In this article, these findings are discussed from TGD point of view.

Keywords: LIGO, gravitational wave, Black Hole, GW170817, GUT, TGD.

1 Introduction

During last year LIGO collaboration has made three important discoveries suggesting the possibility of new physics.

First gravitational waves [3] were detected from what was identified as merging of blackholes at distance of 3 billion lightyears (see `http://tinyurl.com/ybpqla3v`) . An explanation considered in the article is that the stars giving rise to blackholes were rather primitive containing light elements and this would have allowed large masses. The transformation to blackholes could have occurred directly without the intervening supernova phase. There is indeed quite recent finding (see `http://tinyurl.com/y9odpqs2`) showing a disappearance of very heavy star with 25 solar masses suggesting that direct blackhole formation without super-nova explosion is possible for heavy stars. Already the first detection of gravitational radiation raised the question why so heavy black holes.

Here the work with TGD inspired model for "cold fusion" might be of relevance: the model predicts that ordinary nucleosynthesis is preceded by what I call dark nucleosynthesis [10][7] leading to the required high temperature making ordinary nucleosynthesis possible. Could very heavy stars could be produced by this mechanism? Could this mechanism be involved even with the production of metal nuclei inside planets? Contrary to what one might expect, the origin of the metal core of Earth is not at all well-understood.

The observation of GW170817 [2] (see `http://tinyurl.com/ybv9xo6m`) was a further important event. Both gravitational waves and electromagnetic radiation from the collision of two neutron stars fusing to single object were detected. The event occurred at a distance of order 130 Mly (size scale of large voids). The event was a treasure trove of information. Both gravitational waves and gamma rays signal were detected simultaneously and this excludes a large number of models claiming that dark matter does not really exist and predicting that gamma rays and gravitational waves move at different speeds. No neutrinos were observed. This could be explained without additional assumptions. On the other hand, if one extrapolates from the time lag of neutrino burst for SN1987A, the neutrinos should arrive later around December 15 - and their observation would provide support for TGD view as a kind of Christmas gift.

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The latest report from LIGO [1] (see `http://tinyurl.com/ydy89shr`) tells that it has not found any evidence for so called cosmic strings, which are a basic prediction of GUTs and of superstring theories having GUT as long length scale limit. Does TGD survive this finding of LIGO: in other words whether cosmic strings in TGD sense (thickening to flux tubes during cosmic evolution) generate gravitational radiation. The prediction is that free cosmic strings do not radiate. The wormhole contacts created in topological condensation of free cosmic radiate but these entities are basic building bricks of elementary particles so that one can say that cosmic strings do not radiate in GRT sense.

2 Third gravitational wave detection by LIGO collaboration

The news about third gravitational wave detection managed to direct the attention of at least some of us from the doings of Donald J. Trump. Also New York Times (see `http://tinyurl.com/y7xc9xap`) told about the gravitational wave detection by LIGO, the Laser Interferometer Gravitational-Wave Observatory. Gravitational waves are estimated to be created by a black-hole merger at distance of 3 billion light years. The results are published in article "*Observation of a 50-Solar-Mass Binary Black Hole Coalescence at Redshift 0.2*" in Phys Rev Lett [3] (see `http://tinyurl.com/ybpqla3v`).

Two black holes with masses $19 \times M(Sun)$ and $31 \times M(Sun)$ merged to single blackhole hole of with mass of $49 \times M(Sun)$ meaning that roughly one solar mass was transformed to gravitational radiation. During the the climax of the merger, they were emitting more energy in the form of gravitational waves than all the stars in the observable universe.

The colliding blackholes were very massive in all three events. There should be some explanation for this. An explanation considered in the article is that the stars giving rise to blackholes were rather primitive containing light elements and this would have allowed large masses. The transformation to blackholes could have occurred directly without the intervening supernova phase. There is indeed quite recent finding (see `http://tinyurl.com/y9odpqs2`) showing a disappearance of very heavy star with 25 solar masses suggesting that direct blackhole formation without super-nova explosion is possible for heavy stars.

It is interesting to take a fresh look to these blackhole like entities in TGD framework. This however requires brief summary about the formation of galaxies and stars in TGD Universe [9, 11].

1. The simplest possibility allowed by TGD [11] is that galaxies as pearls in necklace are knots (or spagettilike substructures) in long cosmic strings. This does not exclude the original identification as closed strings around long cosmic string. These loops must be however knotted. Galactic super-blackhole could correspond to a self-intersection of the long cosmic string. This view is forced by the experimental finding that for mini spirals, there is volume with radius containing essentially constant density of dark matter. The radius of this volume is 2-3 times larger than the volume containing most stars of the galaxy. This region would contain a galactic knot.

   The important conclusion is that stars would be subknots of these galactic knots as indeed proposed earlier. Part of the magnetic energy would decay to ordinary matter giving rise to visible part of start as the cosmic string thickens. This conforms with the finding that the region in which dark matter density seems to be constant has size few times larger than the region containing the stars (size scale is few kpc).

2. The light beams from supernovas would most naturally arrive along the flux tubes being bound to helical orbits rotating around them. Primordial cosmic string as stars, galaxies, linear structures of galaxies, even elementary particles, hadrons, nuclei, and biomolecules: all these structures would be magnetic flux tubes possibly knotted and linked. The space-time of GRT as a small deformation of M^4 would have emerged from cosmic string dominated phase via the TGD counterpart of inflationary period. The signatures of the primordial cosmic string dominated period would be directly visible in all scales! We would be seeing the incredibly simple truth but our theories would prevent us to become aware about what we are seeing!

The crucial question concerns the dark matter fraction of the star.

1. The fraction depends on the thickness of the deformed cosmic string having originally 1-D projection $E^3 \subset M^4$. If Kähler magnetic energy dominates, the energy per length for a thickened flux tube is proportional to $1/S$, S the area of M^4 projection and thus decreases rapidly with thickening. The thickness of the flux tube would be in minimum about CP_2 size scale of 10^4 Planck lengths. If S is large enough, the contribution of cosmic string to the mass of the star is smaller than that of visible matter created in the thickening.

2. What about very primitive stars - say those associated with LIGO mergers. The proportion of visible matter in star should gradually increase as flux tube thickens. Could the detected blackhole fusion correspond to a fusion of dark matter stars rather than that of Einsteinian blackholes? If the radius of the objects satisfies $r_S = 2GM$, the blackhole like entities are in question also in TGD. The space-time sheet assigable to blachhole according to TGD has however two horizons. The first horizon would be a counterpart of the usual Schwartschild horizons. At second horizon the signature of the induced metric would become Euclidian - this is possible only in TGD. Cosmic string would topologically condense at this space-time sheet.

3. Could most of matter be dark even in the case of Sun? What can we really say about the portion of the ordinary matter inside Sun? The total rate of nuclear fusion in the solar core depends on the density of ordinary matter and one can argue that existing model does not allow a considerable reduction of the portion of ordinary matter.

   There is however also another option - dark fusion - which would be at work in TGD based model of cold fusion [7] (low energy nuclear reactions (LENR) is less misleading term) and also in TGD inspired biology (there is evidence for bio-fusion) as Pollack effect [4, 8], in which part of protons go to dark phase at magnetic flux tubes to form dark nuclear strings creating negatively charged exclusion zone). Dark fusion would give rise to dark proton sequences at magnetic flux tubes decaying by dark beta emission to beta stable nuclei and later to ordinary nuclei and releasing nuclear binding energy.

   Dark fusion could explain the generation of elements heavier than iron not possible in stellar cores [7]. Standard model assumes that they are formed in supernova explosions by so called r-process but empirical data do not support this hypothesis. In TGD Universe dark fusion could occur outside stellar interiors.

4. But if heavier elements are formed via dark fusion, why the same could not be true for the lighter elements? The TGD based model of atomic nuclei represents nucleus as a string like object or several of them possibly linked and knotted. Thickened cosmic strings again! Nucleons would be connected by meson like bonds with quark and antiquark at their ends.

   This raises a heretic question: could also ordinary nuclear fusion rely on similar mechanism? Standard nuclear physics relies on potential models approximating nucleons with point like particles: this is of course the only thing that nuclear physicists of past could imagine as children of their time. Should the entire nuclear physics be formulated in terms of many-sheeted space-time concept and flux tubes? I have proposed this kind of formulation long time ago [6, 5]. What would distinguish between ordinary and dark fusion would be the value of $h_{eff} = n \times h$.

5. Months after writing the above comments I analyzed the books by Steven Krivit about the history of "cold fusion". It is now clear that genuine cold fusion cannot in question. The TGD interpretation is in terms of what I call dark nucleosynthesis (DNS) [10, 7]. DNS would explain both the energy production and production of various isotopes in "cold fusion". DNS could also be the predecessor of the ordinary nucleosynthesis, serving as a kind of warmup band. This unavoidably leads to the idea that "cold fusion" alone could have led to a formation of stars containing relatively light elements

and thus able to have rather large masses: very old stars could be this kind of stars. DNS could even give rise to metal corres of planets and Fe core of Earth could have emerged in this manner.

After this prelude it is possible to speculate about blackholes in the spirit of TGD .

1. Also the interiors of blackholes would contain dark knots and have magnetic structure. This predicts unexpected features such as magnetic moments not possible for GRT blackholes. Also the matter inside blackhole would be dark (the TGD based explanation for Fermi bubbles assumes this [11]). Already the model for the first LIGO event explained the unexpected gamma ray bursts in terms of the twisting of rotating flux tubes as effect analogous to what causes sunspots: twisting and finally reconnection.

2. One must also ask whether LIGO blackholes are actually dark stars with very small amount of ordinary matter. If the radius is indeed equal to Schwarschild radius $r_S = 2GM$ and mass is really what it is estimated to be rather than being systematically smaller, then the interpretation as TGD counterparts of blackholes makes sense. If mass is considerably smaller, the radius would be correspondingly large, and one would not have genuine blackhole. I do not however take this option too seriously.

3. What about collisions of blackholes? Could they correspond to two knots moving along same string in opposite directions and colliding? Or two cosmic strings intersecting and forming a cosmic crossroad with second blackhole in the crossing? Or self-intersection of single cosmic string? In any case, cosmic traffic accident would be in question.

   The second LIGO event gave hints that the spin directions of the colliding blackholes were not the same. This does not conform with the assumption that binary blackhole system was in question. Since the spin direction would be naturally that of long cosmic string, this suggests that the traffic accident in cosmic cross road defined by intersection or self-intersection created the merger. Note that intersections tend to occur (think of moving strings in 3-D space) and could be stablized by gravitational attraction: two string world sheet at 4-D space-time surface have stable intersections just like strings in plane unless they reconnect.

3 Some comments about GW170817

The observation of GW170817 [2] (see http://tinyurl.com/ybv9xo6m) was one of the events of the year in physics. Both gravitational waves and electromagnetic radiation from the collision of two neutron stars fusing to single object were detected. The event occurred at a distance of order 130 Mly (size scale of large voids). The event was a treasure trove of information.

The first piece of information relates to the question about the synthesis of elements heavier than Fe. It is quite generally assumed that the heavier elements are generated in so called r-process involving creation of neutrons fusing with nuclei. One option is that the r-process accompanies supernova explosions but SN1987A did not provide support for this hypothesis: the characteristic em radiation accompanying r-process was not detected. GW170817 generated also em radiation, so called kilonova (see http://tinyurl.com/ycagjeau), and the em radiation accompanying r-process was reported. Therefore this kind of collisions would generate at least part of the heavier elements. In TGD framework also so called dark nucleosynthesis occurring outside stellar interiors and explaining so called nuclear transmutations, which are now rather well-established phenomenon, would also contribute to he generation of heavier elements (and also the lighter ones) [10] (see http://tinyurl.com/y7u5v7j4).

Second important piece of information was that in GW170817 both gravitational waves and gamma ray signal were detected, and the difference between the arrival times was about 1.7 seconds: gamma rays arrived slightly after the gravitational ones. From this the difference between effective propagation velocities between gravitational and em waves is extremely small.

Note that similar difference between neutrino signal and gamma ray signal was measured for SN1987A. Even gamma rays arrived at two separate pulses from SN1987A. In this case the delay was longer and a possible TGD explanation is that the signals arrived along different space-time sheets (one can certainly tailor also other explanations).

1. In the recent case it would seem and gravitons and photons arrived along the same space-time sheet (magnetic flux tubes) or at least that the difference for effective light velocity was extremely small if the sheets were different. Perhaps this is the case for all exactly massless particles. In the case of SN1987A neutrino burst was observed 3 hours after gamma ray burst.

2. From the distance of about .17 MLy one can estimate $\Delta c/c$. If $\Delta c/c$ has the same value for GW17081, the neutrino burst for it should arrive after 2846 hours making 118 days (day=24 hours). One would expect neutrino burst in middle December, kind of Christmass gift! This would explain why neutrinos were not detected in the case of GW170817. The explanation has been that the direction was such that neutrino pulse was to weak to be detected in that direction. If colleagues were mature enough to take TGD seriously, they would be eagerly waiting for the arrival of the neutrino pulse!

Second implication relates to so called modified gravity theories. These theories claim that dark matter and dark energy are not real (for instance MOND suggesting a more or less ad hoc modification of gravitation at very small accelerations and Verlinde's model, which has received a lot of attention recently). Certain class of these models predict a breaking of Equivalence Principle. Gravitons would couple only to the metric created by ordinary matter as predicted by GRT whereas ordinary matter would couple to that created by dark and ordinary matter as predicted by GRT.

Although this kind of models look hopelessly ad hoc (at least to me), they have right to be shown wrong and GW170817 did this (see `http://tinyurl.com/ycm3gnn4`). The point is that the coupling to dark matter besides ordinary matter implies that gamma rays experience additional delay and arrive later than gravitons coupling only to the ordinary matter. This causes what is called Shapiro delay of about 1000 days much longer than the observed 1.7 seconds. Thus these models are definitely excluded. I do not know what this means for the original MOND and for Verlinde's model.

There is an amazing variety of MOND like models there to be killed and another article about what GW170817 managed to do can be found (see `http://tinyurl.com/ybg6mxc4`). Theoretical physics is drowning to a flood of ad hoc models: this is true also in particle physics where great narratives have been dead for four decades now. GW170817 looks therefore like a godly intervention similar to what happened with Babel's tower.

There is a popular article titled "*Seeing One Example Of Merging Neutron Stars Raises Five Incredible Questions*" (see `http://tinyurl.com/ybuzdb4o`) telling that GW100817 seems to be very badly behaving guy challenging the GRT based models for the collisions of neutron stars. Something very fishy seems to be going on and this might be the change for TGD to challenge GRT based models.

1. The naive estimate for the rate of these events is 10 times higher than estimated (suggesting that colliding objects were connected by flux tube somewhat like biomolecules making them possible to find each other in the molecular soup).

2. The mass ejected from the object was much larger than predicted. The signal in UV and optical parts of the spectrum should have lasted about one day. It lasted for two days before getting dimmer.

3. The final state should have been blackhole or magnetar collapsing rapidly into blackhole. It was however supermassive neutron star with mass about 2.74 solar masses. The upper limit is about 2.5 solar masses for non-rotating neutron star so that the outcome should have been a blackhole without any ejecta!

TGD view about blackholes differs from that of GRT. The core region of all stars (actually all physical objects including elementary particles) involves a space-time sheet for which the signature of the induced metric is Euclidian. The signature changes at light-like 3-surface somewhat analogous to blackhole horizon. For blackhole like entities there is also Schwartschild horizong above this horizon. Could this model provide a better model for the outcome of the fusion.

4. Why gamma ray bursts were so strong and in so many directions instead of cone of angular width about 10-15 degrees? Although gamma ray burst was about 30 degrees from the line of sight, it was seen.

   Heavier elements cannot be produced by fusion in stellar interiors since the process requires energy. r-process in the fusions of neutron stars has been proposed as the mechanism, and the radiation spectrum from GW170817 is consistent with this proposal. The so called dark nucleosynthesis proposed in TGD framework to explain nuclear transmutations (or "cold fusion" or low energy nuclear reactions (LENR)) [10]. This mechanism would produce more energy than ordinary nuclear fusion: when dark proton sequence (dark nucleus) transforms to ordinary nucleus almost entire nuclear binding energy is liberated. Could the mechanism producing the heavier elements be dark nuclear fusion also in the fusion of neutron stars. This would have also produced more energy than expected.

4 LIGO: no evidence for cosmic strings

LIGO has reported [1] (see `http://tinyurl.com/ydy89shr`) that it has not found any evidence for so called cosmic strings, which are a basic prediction of GUTs. It is becoming painfully clear that GUTs have led the entire theoretical physics to a wrong track. Regrettably, we have spent for more than four decades at this wrong track now. Also superstring models and M-theory assume GUT as their limit at long length scales so that this finding should finally wake up even the most sleepy colleagues.

As Peter W*it (for some reason Lubos wants to write "o":s as "*":s in this context) tells in N*t Even Wr*ng (see `http://tinyurl.com/glet7y5`), cosmic strings have been one of so called qualitative predictions of many variants of superstring theory. This is true but since Lubos is one of the few remaining superstring fans, Woit's blog post made him very irritated (see `http://tinyurl.com/yaecfr2n`) .

What about TGD? Do I have reasons to get irrirated? Cosmic strings appear also in TGD but are very different objects than those of GUTs. They differ also from those of superstrings theories, where they can appear at the GUT limit or as very long fundamental strings.

4.1 Cosmic strings in GUTs and superstring theories

What mainstream cosmic strings are?

1. In GUTs cosmic strings are 1-D defects associated with singular gauge field configurations. There is a phase, which grows by a multiple of 2π as one goes around the defect line. One has essentially vortex line locally. At the singularity the modulus of field variable associated with the phase must vanish.

   Here comes in the fundamental difference between gauge fields in GUTs and in TGD where they are induced and QFT limit of TGD does not allow either GUT cosmic strings, GUT monopoles, nor instantons implying strong CP breaking plaguing QCD.

2. In superstring theories one also has these defects almost unavoidably if one believes that some kind of GUT defines the long length scale limit of superstring theories. Superstring theories also suggests that fundamental strings somehow give rise to very long fundamental cosmic strings: I cannot say anything about the details of the proposed mechanism.

The dynamics of string like objects is almost universal.

1. The first parameter is string tension μ predicted by GUTs. There are strong bounds on μ in terms of $1/G$. The upper bound $\mu G \simeq 10^{-7}$ emerges from the fact that cosmic strings have not been found yet. The string tension of TGD cosmic strings satisfies this condition: the order of magnitude for the ratio is determined by the ratio $l_P^2/R^2 = 2^{-24} \sim .6 \times 10^{-7}$, where l_P is Planck length scale and R is radius of CP_2 geodesic circle. The tension of cosmic strings involves also Kähler coupling strength.

2. Second parameter characterizes the dynamics of string networks and is reconnection probability p for strings. It would be $p \sim 10^{-1}$ for strings with topological origin (GUT strings) and $p \sim 10^{-3}$ for possibly existing long superstrings. Using these parameters one can build dynamical models and perform numerical simulations. In LIGO article several models are discussed together with their predictions.

Reconnections lead to a generation of oscillating string loops and these would generate gravitational radiation at harmonics of the frequency, which is essentially the inverse of the length of the string. In particular, the kinks and cusps (string moves with light-velocity locally) propagating along these strings would generate gravitational radiation. Concerning the evolution of the string network the ratio of l/a, where a is cosmic time identifiable as the proper-time coordinate of light-cone, is essential.

1. One expects that kinks and cusps correspond to delta function singularities in energy momentum tensor serving as sources of gravitational radiation. In cusps the determinant of 2-D induced metric vanishes and the energy momentum tensor proportional to 2-D contravariant metric diverges like $1/det(g)$. This seems to produce a singularity.

2. Energy momentum tensor serving as the source of gravitational radiation seems to be however only discontinuous at kinks. Naively one might think that the ordinary divergence of energy momentum tensor having delta function singularity tells how much energy momentum goes out from string as gravitational radiation. My guess is that one must add to the action an additional term corresponding to the discontinuity and depending on Christoffel symbols at the discontinuity to describe the curvature singularity. This term would serve as a source of gravitational radiation.

   This term is essentially the second fundamental form for the imbedding of the singularity as a 3-surfaces and its trace would define the interaction term just as the naive picture would lead to expect. The interpretation of this term is essentially as the analog of acceleration and accelerating particle indeed creates radiation, also gravitational radiation. As a matter fact, this kind of term must be also added in 2-D case to the curvature scalar to get correctly Gauss-Bonnet law for polygons having corners.

4.2 Do TGD cosmic strings produce gravitational radiation?

The cosmic strings in TGD sense are different from those in the sense of GUTs and superstring theories. To discuss the question what TGD cosmic strings are and whether they radiate one must say something general about the dynamics of space-time surfaces in TGD.

4.2.1 There are two kinds of space-time surfaces in TGD Universe

There are two kinds of space-time surfaces in TGD Universe. These two kinds fo space-time surfaces appear at the boths sides of $M^8 - H$ duality: here one has $H = M^4 \times CP_2$. In the following I stay at the H-side of the duality.

There is a rather precise analogy with the vision about what happens in particle reactions. External particles decouple from interactions and interactions take place in interaction regions, where interactions are in some sense coupled on. This is realized for the preferred extremals of the action determining space-time surfaces in rather precise sense. The twistor lift of TGD predicts that the action is sum of Kähler action and volume term analogous to cosmological term.

1. The preferred exremals can be minimal surfaces in which case field equations are satisfied separately for Kähler action and volume term: the two interactions effectively decouple. The dynamics reduces to holomorphy conditions and coupling constants disappear completely from it. This corresponds to the universal dynamics of quantum criticality.

   The minimal 4-surfaces are direct 4-D analogs of geodesic lines, free particles. Also cosmic strings are surfaces or this kind and presumably also the magneti flux tubes. In Zero Energy Ontology (ZEO) these surfaces represent external particles entering or leaving causal diamond (CD). Free particles do not emit any kind of radiation and this would be indeed realized now.

2. Inside CDs Kähler action and volume term do not decouple and there is genuine interaction between them. One does not have minimal surfaces anymore and coupling constants appear in the dynamics. In this region the emission of radiation and also of gravitational radiation is possible.

4.2.2 Cosmic strings in TGD sense

Also TGD predicts what I call cosmic strings.

1. Ideal cosmic strings a la TGD string like objects, space-time surfaces. They are not singular densities of matter in 4-D space-time which would be small deformation of Minkowski metric. Rather, they are 4-D surfaces havng 2-D string world sheets as M^4 projection. String world sheet and string like object are minimal surfaces and should emit no radiation.

   Remark: Since M^4 projection is not 4-D GRT limit does not make sense for cosmic strings and the GRT based calculation for gravitational radiation does not apply in TGD framework.

2. Cosmic strings dominate the dynamics in very early universe. In reasonable approximation one could speak about gas of cosmic strings in M^4 - or strictly speaking in $M^4 \times CP_2$. The transition to radiation dominated era is the TGD counterpart for inflationary period: the space-time in GRT sense emerges as space-time sheets having 4-D M^4 projection. Stringlike objects topologically condense at 4-D space-time sheets. Also their M^4 projection becomes 4-D and begins to thicken during cosmic evolution so that magnetic field strength starts to weaken.

   Cosmic strings can carry Kähler magnetic monopole flux explaining the mysterious long ranged magnetic fields in cosmological scales. Reconnection and formation of closed loops is possible. Many-sheetedness is an important aspect: there are flux tubes within flux tubes.

   Cosmic strings/magnetic flux tubes play a key role in the formation of galaxies and larger (and even smaller) structures. Galaxies are along cosmic strings like pearls along necklace: the simplest model assumes that pearls are knots along cosmic strings (note the amusing analogy with DNA having coding regions as nucleosomes along it). Flux tubes and their reconnections play also key role in TGD inspired quantum biology.

4.2.3 Does TGD survive the findings of LIGO?

The question of the title reduces to the question whether the cosmic strings in TGD sense emit gravitational radiation.

1. If cosmic strings are idealizable as minimal surfaces and therefore as stationary states outside CDs they do not produce any kind of radiation. Radiation and gravitational radiation can emerge only in space-time regions, where there is a coupling between Kähler action and volume term. In particular, the purely internal dynamics of ideal cosmic strings cannot produce gravitational radiation.

There is also the question about whether kinks and cusps are possible for preferred extremals satisfying extremely tight symmetry conditions realizing strong form of holography. If not, they are not expected at QFT limit either. In fact, kinks seem impossible whereas the orbits of wormhole throats represent analogs of cusps to be discussed below.

2. One can of course argue that topologically condensed thickened cosmic strings actually interact and ought to be described as something inside CD. In any case, there is a coupling between Kähler degrees of freedom and geometry of string and this means that GRT based model cannot apply.

   One can ask whether GRT based calculation for the emission of gravitational radiation makes sense for thickened cosmic strings having 4-D M^4 projection. This requires going to the GRT-QFT limit involving the approximation of the many-sheeted space-time with GRT space-time: this means replacing sheets with single sheet and identifying deviation of the metric from M^4 metric and gauge potentials with sums of the corresponding induced quantities.

   In topological condensation 4-D wormhole contacts with Euclidian signature of the induced metric are generated, and the 3-D boundaries between Euclidian and Minkowskian space-time regions defining the boundaries of wormhole contacts have light-like metric and are completely analogous to cusps of cosmic strings. These surfaces would serve as sources of radiation at GRT limit. However, in TGD framework wormhole contacts are identified as basic building bricks of elementary particles so that the emission of gravitational radiation would be due to elementary particles at space-time sheets carrying magnetic fields! If kinks are absent as preferred extremal property suggests, one can say that cosmic strings do not radiate in GRT sense in TGD.

3. The role of cosmic strings/magnetic flux tubes in the generation of gravitational radiation would be different. On basis of findings of LIGO, the observed rate for the collisions of blackholes and neutron stars is suspiciously high. How do they find each other more often than expected? This would be the case if these objects are associated with cosmic strings and propagate along them. Cosmic strings indeed have radial gravitational field giving rise to constant velocity spectrum whereas the motion along string is free motion.

   Also stars could be located along cosmic string forming a knot-like structure of long cosmic string containing galaxies as knots. Knot would define the core region of galaxy with approximately constant mass density difficult to explain in the halo model predicting a peak in the density of dark matter. Also stars could be knots but in shorter length scale. In molecular biology flux tubes connecting biomolecules to form a network would make it possible biomolecules to find each other in the molecular crowd.

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