LIGO and TGD

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Abstract

The recent detection of gravitational radiation from a merger of blackholes by LIGO detector initiated a new era in astronomy. The detection allows to sharpen the TGD based view about gravitational radiation, in particular to test the proposal that gravitons propagate as dark gravitons with very large value of Planck constant along magnetic flux tubes. Since classical (no dependence of $heff$) detection of gravitational waves rather than direct detection of gravitons is in question, it is not too surprising that the TGD picture survives. Also a gamma ray burst was observed .4 seconds after the merger and is very probably associated with it. In TGD framework the natural proposal is that this burst arrived as dark cyclotron radiation along the dark flux tubes carrying also the dark gravitons. The energy conserving transformation of the ordinary cyclotron radiation created in the ultra-strong magnetic field of the blackhole to dark photons could have generated the gamma ray pulse. The hypothesis allows to estimate the strength of magnetic field at magnetic flux tubes. The value is consistent with the order of magnitude for intergalactic magnetic fields.

1 Introduction

The recent detection of gravitational radiation by LIGO [E7] (see the posting of Lubos at `http://tinyurl.com/z6mruqk` and the article `http://tinyurl.com/ja2uraj`) can be seen as birth of gravito-astronomy. The existence of gravitational waves is however an old theoretical idea: already Poincare proposed their existence at the time when Einstein was starting the decade lasting work to develop GRT (see `http://tinyurl.com/jdbg4k2`).

Gravitational radiation has not been observed hitherto. This could be also seen as indicating that gravitational radiation is not quite what it is believed to be and its detection fails for this reason. This has been my motivation for considering the TGD inspired possibility that part or even all of gravitational radiation could consist of dark gravitons [K6]. Their detection would be different from that for ordinary gravitons and this might explain why they have not been detected although they are present (Hulse-Taylor binary).

In this respect the LIGO experiment provided extremely valuable information: the classical detection of gravitational waves - as opposed to quantum detection of gravitons - does not seem to differ from that predicted by GRT. On the other hand, TGD suggests that the gravitational radiation between massive objects is mediated along flux tubes characterized by dark gravitational Planck constant $\hbar_{gr} = GMm/v_0$ identifiable as $\hbar_{eff} = n \times \hbar$ [K8, K6]. This allows to develop in more detail TGD view about the classical detection of dark gravitons.

A further finding was that there was an emission of gamma rays [E4] .4 seconds after the merger. The proposal that dark gravitons arrive along dark magnetic flux tubes inspires the question whether these gamma rays were actually dark cyclotron radiation in extremely weak magnetic field associated with these flux tubes. There was also something anomalous involved. The mass scale of the merging blackholes deduced from the time evolution for so called chirp mass was 30 solar masses and roughly twice too large as compared to the upper bound from GRT based models (see `http://tinyurl.com/zehmcao`).

2 Some history and observations

The evolution of the theory of gravitational radiation involves strange twists as also the evolution of the experimental side.

2.1 Development of theory of gravitational radiation

A brief summary about the development of theory of gravitational radiation is useful.

1. After having found the final formulation of GRT around 1916 after ten years hard work Einstein found solutions representing gravitational radiation by linearizing the field equations. The solutions are very similar in form to the radiation solutions of Maxwell's equations. The interpretation as gravitational radiation looks completely obvious in the light of after wisdom but the existence of gravitational radiation was regarded even by theoreticians far from obvious until 1957. Einstein himself wrote a paper claiming that gravitons might not exist after all: fortunately the peer review rejected it (see `http://tinyurl.com/ho857g8`)!

2. During 1916 Schwartschild published an exact solution of field equations representing a non-rotating black hole. At 1960 Kerr published an exact solution representing rotating blackhole. This gives an idea about how difficult the mathematics involved is.

3. After 1970 the notion of quasinormal mode was developed. Quasinormal modes are like normal modes and characterized by frequencies. Dissipation is however taken into account and this makes the frequencies complex. In the picture representing the gravitational radiation detected by LIGO, the damping is clearly visible after the maximum intensity is reached. These modes represent radiation, which can be thought of as incoming radiation totally reflected at horizon. These modes are needed to describe gravitational radiation after the blackhole is formed.

4. After 1990 post-Newtonian methods and numerical relativity developed and extensive calculations became possible allowing also precise treatment of the merger of two blackholes to single one.

I do not have experience in numerics nor in findings solutions to field equations of GRT. General Coordinate Invariance is extremely powerful symmetry but it also makes difficult the physical interpretation of solutions and finding of them. One must guess the coordinates in which everything is simple and here symmetries are of crucial importance. This is why I have been so enthusiastic about sub-manifold gravity: M^4 factor of imbedding space provides preferred coordinates and physical interpretation becomes straightforward. In TGD framework the construction of extremals - mostly during the period 1980-1990 - was surprisingly easy thanks to the existence of the preferred coordinates. In TGD framework also conservations laws are exact and geodesic motion can be interpreted in terms of analog of Newton's equations at imbedding level: at this level gravitation is a genuine force and post-Newtonian approximation can be justified in TGD framework.

2.2 Evolution of the experimental side

1. The first indirect proof for gravitational radiation was Hulse-Taylor binary pulsar (see `http://tinyurl.com/hmjuse9`). The observed increase of the rotation period could be understood as resulting from the loss of rotational energy by gravitational radiation.

2. Around 1960 Weber suggests a detector based on mass resonance with resonance frequency 1960 Hz. Weber claimed of detecting gravitational radiation on daily basis but his observations could not be reproduced and were probably due to an error in computer program used in the data analysis.

3. At the same time interferometers as detectors were proposed. Interferometer has two arms and light travels along both arms arms, is reflected from mirror at the end, and returns back. The light signals from the two arms interfere at crossing. Gravitational radiation induces the oscillation of the distance between the ends of interferometer arm and this in turn induces an oscillating phase shift. Since the shifts associated with the two arms are in general different, a dynamical interference pattern is generated. Later laser interferometers emerged.

   One can also allow the laser light to move forth and back several times so that the phase shifts add and interference pattern becomes more pronounced. This requires that the time spent in moving forth and back is considerably shorter than the period of gravitational radiation. Even more importantly, this trick also allows to use arms much shorter than the wavelength of gravitational radiation: for 35 Hz defining the lower bound for frequency in LIGO experiment the wavelength is of the order of Earth radius!

4. One can also use several detectors positioned around the globe. If all detectors see the signal, there are good reasons to take it seriously. It becomes also possible to identity precisely the direction of the source. A global network of detectors can be constructed.

5. The fusion of two massive blackholes sufficiently near to Earth (now they were located at distance of about Gly!) is optimal for the detection since the total amount of radiation emitted is huge.

2.3 What was observed?

LIGO detected an event that lasted for about .2 seconds. The interpretation was as gravitational radiation and numerical simulations are consistent with this interpretation. During the event the frequency of gravitational radiation increased from 35 Hz to 250 Hz. Maximum intensity was reached at 150 Hz and correspond to the moment when the blackholes fuse together. The data about the evolution of frequency allows to deduce information about the source if post-Newtonian approximation is accepted and the final state is identified as Kerr blackhole.

1. The merging objects could be also neutron stars but the data combined with the numerical simulations force the interpretation as blackholes. The blackholes begin to spiral inwards and since energy is conserved (in post-Newtonian approximation), the kinetic energy increases because potential energy decreases. The relative rotational velocity for the fictive object having reduced mass increases. Since gravitational radiation is emitted at the rotational frequency and its harmonics, its frequency increases and the time development of frequency

codes for the time development of the rotational velocity. This rising frequency is in audible range and known as chirp.

In the recent situation the rotational frequency increases from 35 Hz to maximum of 150 Hz at which blackholes fuse together. After that a spherically symmetric blackhole is formed very rapidly and exponentially damped gravitational radiation is generated (quasinormal modes) as frequency increases to 250 Hz. A ball bouncing forth and back in gravitational field of Earth and losing energy might serve as a metaphor.

2. The time evolution of the frequency of radiation coded to the time evolution of interference pattern provides the data allowing to code the masses of the initial objects and of final state object using numerical relativity. So called chirp mass can be expressed in two manners: using the masses of fusing initial objects and the rotation frequency and its time derivative. This allows to estimate the masses of the fusing objects. They are 36 and 29 solar masses respectively. The sizes of these blackholes are obtained by scaling from the blackhole radius 3 km of Sun. The objects must be blackholes. For neutron stars the radii would be much larger and the fusion would occur at much lower rotation frequency.

3. Assuming that the rotating final state blackhole can be described as Kerr's blackhole, one can model the situation in post-Newtonian approximation and predict the mass of the final state blackhole. The mass of the final state blackhole would be 62 solar masses so that 3 solar masses would transform to gravitational radiation! The intensity of the gravitational radiation at peak was more than the entire radiation by stars int the observed Universe. The second law of blackhole thermodynamics holds true: the sum of mass squared for the initial state is smaller than the mass squared for the final state ($32^2 + 29^2 \leq 62^2$).

3 Are observations consistent with TGD predictions?

The general findings about masses of blackholes and their correlations with the frequency and about the net intensity of radiation are also predictions of TGD. The possibility of dark gravitons as large h_{eff} quanta however brings in possible new effects and might affect the detection. The consistency of the experimental findings with GRT based theory of detection process raises critical question: are dark gravitons there?

3.1 Some TGD background for LIGO observations

Some TGD background is in order before discussion of various findings from LIGO.

3.1.1 About the relationship between GRT and TGD

The proposal is that GRT plus standard model defines the QFT limit of TGD replacing many-sheeted space-time with slightly curved region of Minkowski space carrying gauge potentials defined as sums of the components of the induced spinor connection and the deviation of metric from flat metric as sum of similar deviations for space-time sheets [K12]. This picture follows from the assumption that the test particle touching the space-time sheets experience the sum of the classical fields associated with the sheets.

The open problems of GRT limit of TGD have been the origin of Newton's constant - CP_2 size is almost four orders of magnitude longer than Planck length.Amusingly, a dramatic progress occurred in this respect just during the week when LIGO results were published.

The belief has been that Planck length is genuine quantal scale not present in classical TGD. The progress in twistorial approach to classical TGD however demonstrated that this belief was wrong. The idea is to lift the dynamics of 6-D space-time surface to the dynamics of their 6-D twistor spaces obeying the analog of the variational principle defined by Kähler action. I had thought that this would be a passive reformulation but I was completely wrong [L3] [L3] (see `http://tinyurl.com/zjgmax6`).

1. The 6-D twistor space of the space-time surface is a fiber bundle having space-time as base space and sphere as fiber and assumed to be representable as a 6-surface in 12-D twistor

space $T(M^4) \times T(CP_2)$. The lift of Kähler action to Kähler action requires that the twistor spaces $T(M^4)$ and $T(CP_2)$ have Kähler structure in generalized sense. These structures exist only for S^4, E^4 and its Minkowskian analog M^4 and CP_2 so that TGD is completely unique if one requires the existence of twistorial formulation. In the case of M^4 one has a hybrid of complex and hyper-complex structure.

2. The radii of the two spheres bring in new length scales. The radius in the case of CP_2 is essentially CP_2 radius R. In the case of M^4 the radius is very naturally Planck length so that the origin of Planck length is understood and it is purely classical notion whereas Planck mass and Newton's constant would be quantal notions.

3. The 6-D Kähler action must be made dimensionless by dividing with a constant with dimensions of length squared. The scale in question is actually the area of $S^2(M^4)$, not the inverse of cosmological constant as the first guess was. The reason is that this would predict extremely large Kähler coupling strength for the CP_2 part of Kähler action.

   There are however two contributions to Kähler action corresponding to $T(CP_2)$ and $T(M^4)$ and the corresponding Kähler coupling strengths - the already familiar α_K and the new $\alpha_K(M^4)$ - are independent. The value of $\alpha_K(M^4) \times 4\pi R(S^2(M^4)$ corresponds essentially to the inverse of cosmological constant and to a length scale which is of the order of the size of Universe in the recent cosmology. Both Kähler coupling strengths are analogous to critical temperature and are predicted to have a spectrum of values. According to the earlier proposal, $\alpha_K(M^4)$ would be proportional to p-adic prime $p \simeq 2^k$, k prime, so that in very early times cosmological constant indeed becomes extremely large. This has been the problem of GRT based view about gravitation. The prediction is that besides the volume term coming from $S^(M^4)$ there is also the analog of Kähler action associated with M^4 but is extremely small except in very early cosmology.

4. A further new element is that TGD predicts the possibility of large $h_{eff} = n \times h$ gravitons. One has $\hbar_{eff} = \hbar_{gr} = GMm/v_0$, where v_0 has dimensions of velocity and satisfies $v_0/c < 1$: the value of v_0/c is of order $.5 \times 10^{-3}$ for the inner planets. h_{gr} seems to be absolutely essential for understanding how perturbative quantum gravitation emerges.

   What is nice is that the twistor lift of Kähler action suggests also a concrete explanation for $h_{eff}/h = n$. It would correspond to winding number for the map $S^2(X^4) \rightarrow S^2(M^4)$ and one would indeed have covering of space-time surface induced by the winding as assumed earlier. This covering would have the special property that the base base for each branch of covering would reduce to same 3-surface at the ends of the space-time surface at the light-like boundaries of causal diamond (CD) defining fundamental notion in zero energy ontology (ZEO).

Twistor approach thus shows that TGD is completely unique in twistor formulation, explains Planck length geometrically, predicts cosmological constant and assigns p-adic length scale hypothesis to the cosmic evolution of cosmological constant, and also suggests an improved understanding of the hierarchy of Planck constants.

3.1.2 Can one understand the detection of gravitational waves if gravitons are dark?

The problem of quantum gravity is that if the parameter $GMm/h = Mm/m_P^2$ associated with two masses characterizes the interaction strength and is larger than unity, perturbation theory fails to converge. If one can assume that there is no quantum coherence, the interactions can be reduced to those between elementary particles for which this parameter is below unity so that the problem would disappear. In TGD framework however fermionic strings mediate connecting partonic 2-surface mediate the interaction even between astrophysical objects and quantum coherence in astrophysical scales is unavoidable.

The proposal is that Nature has been theoretician friendly and arranged so that a phase transition transforming gravitons to dark gravitons takes place so that Planck constant is replaced with $\hbar_{gr} = GMm/v_0$. This implies that $v_0/c < 1$ becomes the expansion parameter and perturbation theory converges. Note that the notion of h_{gr} makes sense only of one has $Mm/m_P^2 > 1$. The notion generalizes also to other interactions and their perturbative description when the interaction strength is large. Plasmas are excellent candidates in this respect.

1. The notion of h_{gr} was proposed first by Nottale from quite different premises was that planetary orbits are analogous to Bohr orbits and that the situation is characterized by gravitational Planck constant $\hbar_{gr} = GMm/v_0$. This replaces the parameter $GMm/\hbar$ with v_0 as perturbative parameter and perturbation theory converges. h_{gr} would characterize the magnetic flux tubes connecting masses M and m along which gravitons mediating the interaction propagate.

   According to the model of Nottale [E3] for planetary orbits as Bohr orbits the entire mass of star behaves as dark mass from the point of view particles forming the planet. $\hbar_{gr}$ appears as in the quantization of angular momentum and if dark mass $M_D < M$ is assumed, the integer characterizing the angular momentum must be scaled up by M/M_D. In some sense all astrophysical objects would behave like quantum coherent systems and many-sheeted space-time suggests that the magnetic body of the system along which gravitons propagate is responsible for this kind of behavior.

2. The crucial observation is that h_{gr} depends on the product of interacting masses so that h_{gr} characterizes a pair of systems satisfying $Mm/m_P^2 > 1$ rather than either mass. If so, the gravitons at magnetic flux tubes mediating gravitational interaction between masses M and m are always dark and have $h_{gr} = h_{eff}$. One cannot say that the systems themselves are characterized by h_{gr}. Rather, only the magnetic bodies or parts of them can be characterized by h_{gr}. The magnetic bodies can be associated with mass pairs and also with self interactions of single massive object (as analog of dipole field).

3. The general vision is that ordinary particles and large h_{eff} particles can transform to each other at quantum criticality [K3]. Above temperatures corresponding to critical temperature particle would be ordinary, in a finite temperature range both kind of particles would be present, and below the lower critical temperature the particles would be dark. High T_c super-conductivity would provide a school example about this.

One would expect that for pairs of quantum coherent objects satisfying $GMm/h > 1$, the graviton exchange is by dark gravitons. This could affect the model for the detection of gravitons.

1. The first thing to notice is that the detectors can evaluate the distance of the source only by using the GRT prediction for the power of radiation and observed intensity. If alternative theory predicts different power (say if in the recent case dark gravitons remain un-detected), the distance of the source deduced from the data is changed.

2. Since Planck constant does not appear in classical physics, one might argue that the classical detection does not distinguish between dark and ordinary gravitons. Gravitons corresponds classically to radiation with same frequency but amplitude scaled up by $\sqrt{n}$. One would obtain for $h_{gr} > 1$ a sequence of pulses with large amplitude length oscillations rather than continuous oscillation as in GRT. The average intensity would be same as for classical gravitational radiation.

   Interferometers detect gravitational radiation classically as distance oscillations and the finding of LIGO suggests that all of the radiation is detected. Irrespective of the value of h_{eff} all gravitons couple to the geometry of the measuring space-time sheets. This looks very sensible in the geometric picture for this coupling. A more quantitative statement would be that dark and ordinary gravitons do not differ for detection times longer than the oscillation period. This would be the case now.

   The detection is based on laser light which goes forth and back along arm. The total phase shift between beams associated with the two arms matters and is a sum over the shifts associated with pulses. The quantization to bunches should be smoothed out by this summation process and the outcome is same as in GRT since average intensity must be same irrespective of the value of h_{gr}. Since all detection methods use interferometers there would be no difference in the detection of gravitons from other sources.

3. The quantum detection h_{eff} gravitons - as opposed to classical detection - is expected to differ from that of ordinary gravitons. Dark gravitons can be regarded as bunches of n ordinary gravitons and thus is n times higher energy. Genuine quantum measurement would correspond to an absorption of this kind of giant graviton. Since the signal must be "visible" dark gravitons must transform to ordinary gravitons with same energy in the detection. For 35 Hz graviton the energy would have been $GMm/v_0\hbar$ times the energy or ordinary graviton with the same frequency. This would give energy of $19(c/v_0)$ MeV: one would have gravitational gamma rays. The detection system should be quantum critical. The transformation of dark gravitons with frequency scale done by $1/n$ and energy increased correspondingly would serve as a signature for darkness.

   Living systems in TGD Universe are quantum critical and bio-photons are interpreted as dark photons with energies in visible and UV range but frequencies in EEG range and even below [K7]. It can happen that only part of dark graviton radiation is detected and it can remain completely undetected if the detecting system is not critical. One can also consider the possibility that dark gravitons first decay to a bunch of n ordinary gravitons. Now however the detection of individual gravitons is impossible in practice.

It is interesting to look what one obtains if one assumes that the collapse occurs to the gravitational Compton radius $r_{gr} = \hbar_{gr}/M$ of the resulting blackhole. Using $\hbar_{gr} = GMm/v_0$ (I have used erratic formula $h_{gr} = GMm/v_0$ in some texts), the value of this radius is $r_{gr} = GM/v_0$ $(c = 1)$. The post-Newtonian parameter $v = (GM\pi f)^{1/3}$ interpreted as relative velocity in in the article equals to $v \simeq .62$. $v_0 = v$ gives $r_{gr}/r_s = .5/.62 < 1$ (note that f is gravitational wave frequency which is twice the orbital frequency). The intuitive expectation is that $v_0 = 1/2$ defines upper limit for v_0. For this value one would have $r_s = r_{gr}$ and the outcome would be essentially the same as for ordinary blackhole collapse.

3.2 A gamma ray pulse was detected .4 seconds after the merger

The Fermi Gamma-ray Burst Monitor detected 0.4 seconds after the merger a pulse of gamma rays with red shifted energies about 50 keV [E4] (see the posting of Lubos at `http://tinyurl.com/huyny49` and the article from Fermi Gamma Ray Burst Monitor at `http://tinyurl.com/zpmx3rm`). At the peak of gravitational pulse the gamma ray power would have been about one millionth of the gravitational radiation. Since the gamma ray bursts are not detected too often (1 per day), it is rather plausible that the pulse comes from the same source as the gravitational radiation. The simplest model for blackholes does not suggest this but it is not difficult to develop more complex models involving magnetic fields.

Could this observation be seen as evidence for the assumption that dark gravitons are associated with magnetic flux tubes?

1. The radiation would be dark cyclotron gravitation generated at the magnetic flux tubes carrying the dark gravitational radiation at cyclotron frequency $f_c = qB/m$ and its harmonics (q denotes the charge of charge carrier and B the intensity of the magnetic field and its harmonics and with energy $E = h_{eff}eB/m$.

2. If $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ holds true, one has $E = GMeB/v_0$ so that all particles with same charge respond at the same the same frequency irrespective of their mass: this could be seen as a magnetic analog of Equivalence Principle. The energy 50 keV corresponds to frequency $f \sim 5 \times 10^{18}$ Hz. For scaling purposes it is good to remember that the cyclotron frequency of electron in magnetic field $B_{end} = .2$ Gauss (value of endogenous dark magnetic field in TGD inspired quantum biology) is $f_c = .6$ Mhz.

   From this the magnetic field needed to give 50 keV energy as cyclotron energy would be $B_{ord} = (f/f_c)B_{end} = .4$ GT corresponds to electrons with ordinary value of Planck constant the strength of magnetic field. If one takes the redshift of order $v/c \sim .1$ for cosmic recession velocity at distance of Gly one would obtain magnetic field of order 4 GT. Magnetic fields of with strength of this order of magnitude have been assigned with neutron stars.

3. On the other hand, if this energy corresponds to $\hbar_{gr} = GMm_ec/v_0$ one has $B = (h/h_{gr})B_{ord} = (v_0 m_P^2/Mm_e) \times B_{ord} \sim (v_0/c) \times 10^{-11}$ T $(c = 1)$. This magnetic field is rather weak (fT is

the bound for detectability) and can correspond only to a magnetic field at flux tube near Earth. Interstellar magnetic fields between arms of Milky way are of the order of 5×10^{-10} T and are presumably weaker in the intergalactic space.

4. Note that the energy of gamma rays is by order or magnitude or two lower than that for dark gravitons. This suggests that the annihilation of dark gamma rays could not have produced dark gravitons by gravitational coupling bilinear in collinear photons.

One can of course forget the chains of mundane realism and ask whether the cyclotron radiation coming from distant sources has its high energy due to large value of h_{gr} rather than due to the large value of magnetic field at source. The presence of magnetic fields would reflects itself also via classical dynamics (that is frequency). In the recent case the cyclotron period would be of order $(.03/v_0)$ Gy, which is of the same order of magnitude as the time scale defined by the distance to the merger.

In the case of Sun the prediction for energy of cyclotron photons would be $E = [v_0(Sun)/v_0] \times [M(Sun)/M(BH)] \times 50$ keV $\sim [v_0(Sun)/v_0]$ keV. From $v_0(Sun)/c \simeq 2^{-11}$ one obtains $E = (c/v_0) \times .5$ eV $\geq .5$ eV. Dark photons in living matter are proposed to correspond to $h_{gr} = h_{eff}$ and are proposed to transform to bio-photons with energies in visible and UV range [K7].

Good dialectic would ask next whether both views about the gamma rays are actually correct. The "visible" cyclotron radiation with standard value of Planck constant at gamma ray energies would be created in the ultra strong magnetic field of blackhole, would be transformed to dark gamma rays with the same energy, and travel to Earth along the flux tubes. In TGD Universe the transformation ordinary photons to dark photons would occur in living matter routinely. One can of course ask whether this transformation takes place only at quantum criticality and whether the quantum critical period corresponds to the merger of blackholes.

The time lag was .4 second and the merger event lasted .2 seconds. Many-sheeted space-time provides one possible explanation. If the gamma rays were ordinary photons so that dark gravitons would have travelled along different flux tubes, one can ask whether the propagation velocities differed by $\Delta c/c \sim 10^{-17}$. In the case of SN1987A neutrino and gamma ray pulses arrived at different times and neutrinos arrived as two different pulses [K11] so that this kind of effect is not excluded. Since the light-like geodesics of the space-time surface are in general not light-like geodesics of the imbedding space signals moving with light velocity along space-time sheet do not move with maximal signal velocity in imbedding space and the time taken to travel from A to B depends on space-time sheet. Could the later arrival time reflect slightly different signal velocities for photons and gravitons?

Could one imagine a function for the gamma ray pulse possibly explaining also why it came considerably later than gravitons (0.4 seconds after the merger which lasted 2. seconds)? This function might relate to the transfer of surplus angular momentum from the system.

1. The merging blackholes were reported to have opposite spins. Opposite directions of spins would make the merger easier since local velocities at the point of contact are in same direction. The opposite directions spins suggest an analogy with two vortices generated from water and this suggests that their predecessors were born inside same star. There is also relative orbital angular momentum forming part of the spin of the final state blackhole, which was modelled as a Kerr blackhole. Since the spins of blackholes were opposite, the main challenge is to understand the transition to the situation in all matter has same direction of spin. The local spin directions must have changed by some mechanism taking away spin.

2. Magnetic analogs blackholes seem to be needed. They would be analogs of magnetars, which are pulsars with very strong magnetic fields. Magnetic fields are needed to carry out angular momentum from the matter as blackhole is formed. Same should apply now. Outgoing matter spirals along the helical jets (and carries away the spin which is liberated as the rotating matter in two spinning blackholes slows down to rest and the orbital angular momentum becomes the total spin.

3. If cyclotron adiation left .4 later, it would be naturally assignable to the liberation of temporarily stored surplus angular momentum which blackhole could not carry stably. This cyclotron radiation could have carried out the surplus angular momentum. Amusingly, it could be also seen as a dark analog of Hawking radiation.

Here one must be ready to update the beliefs about what black hole like objects are. About their interiors empirical data tell of course nothing.

1. The exteriors could contain magnetic fields and must do so in TGD Universe. Kerr-Newman solution represents a rotating magnetic blackhole solution of Einstein-Maxwell theory (see Appendix). It carries quadrupole magnetic field so that one can say that "blackhole has no hair theorem" stating that blackhole is completely characterized by conserved charges associated with long range interactions: mass, angular momentum and electric charge fails for Kerr-Newman solution. The solution is is however unphysical containing closed time-like curves: the space-like ring singularity of Kerr solution is transformed to infinitely long time-like curve when charge is introduced. In TGD framework this solution seems very implausible even at GRT limit of the theory since closed time-like geodesics are impossible for space-time surfaces. What is required is analog of blackhole with magnetic monopole charge or dipole moment and to my best knowledge no such solutions are known for Einstein-Maxwell theory.

2. No hair theorem has been challenged quite recently by Hawking (for TGD inspired commentary [L2] see `http://tinyurl.com/yby3r3ec`). This suggest the possibility that higher multiple moments characterize blackhole like entities. An extension of $U(1)$ gauge symmetries allowing gauge transformations, which become constant in radial direction at large distances but depend on angle degrees of freedom, is in question. In TGD framework the situation is analogous but much more general and super-symplectic and other symmetries with conformal structure extend the various conformal symmetries and allow to understand also the hierarchy of Planck constants in terms of a fractal hierarchy of symmetry breakins to sub-algebra isomorphic with the full algebra of symmetries in question [K3].

3. There exist also experimental data challenging the no-hair theorem. The supermassive blackhole like entity near the galactic center is known to have a magnetic field (see `http://tinyurl.com/hazseka`) and thus magnetic moment if the magnetic field is assignable to the blackhole itself rather than matter surrounding it.

Be as it may, any model should explain why the cyclotron radiation pulse came .4 seconds later than gravitaton pulse rather than at the same time. Compared to .2 seconds for blackhole formation this is quite a long time.

1. Suppose that blackhole like objects have - as any gravitating astrophysical object in TGD Universe must have - a magnetic body making possible the transfer of gravitons and carrying classical gravitational fields. Suppose that radial monopole flux tubes carrying gravitons can carry also BE condensates for which charged particles have varying mass m. $\hbar_{gr} = GMm/v_0 = \hbar_{eff} = n \times \hbar$ implies that particles with different masses reside at their own flux tubes like books in book shelves - something very important in TGD inspired quantum biology [K7].

   One might argue that $\hbar_{gr}$ serves as a very large spin unit and makes the storage very effective but here one must be very cautious: spin fractionization suggested by the covering property of space-time sheets could scale down the spin unit to $\hbar/n$. I do not really understand this issue well enough. In any case, already the spontaneously magnetized BE condensate with relative angular momentum of Cooper makes at pairs of helical flux tubes possible effective angular momentum storage.

2. The spontaneously magnetized dark Bose-Einstein condensate would consist of charged bosons - say charged fermion pairs with members located at parallel flux tubes as in the TGD inspired model of hight T_c superconductor with spin $S = 1$ Cooper pairs. This BE condensate would be ideal for the temporary storage of surplus spin and relative angular momentum of members of pairs at parallel helical flux tubes. Orbital angular momentum assignable to the flux tubes twisted by the rotation is much more effective storage mechanism than dark magnetization since orbital angular momentum has typically much larger values spin. This angular momentum would have been radiated away as a gamma ray pulse in a quantum phase transition.

   The first possibility is that this phase transition is to a state without dark spontaneous magnetization. A more promising possibility is that the transition corresponds (also) to a reconnection of flux tubes leading to un-knotting of the flux tubes and liberation of energy and angular momentum as gamma ray pulse. In TGD framework the twisting and braiding of the magnetic monopole flux tubes induced by the rotation of the blackhole like entity store the surplus rotational energy and angular momentum of merging blackholes to magnetic body liberated as the magnetic flux tubes reconnect leading to the unk-knotting the braid. In Sun the solar spot cycle with a period of 11 years corresponds to this kind of periodic braiding and un-braiding by re-connections.

3. In TGD framework there are reasons to ask whether the magnetic field associated with blackhole consists of flux tubes carrying essentially radial monopole flux. If electric charge is involved as the fact that all metrics behaving like Schwartschild metric asymptotically carry arbitrarily small but non-vanishing gauge charge(s), it could be transferred along same flux tubes with self dual Kähler form giving rise to self-dual U(1) gauge field. Also the charged matter in the accretion disk around blackhole could generate magnetic field. Since no currents are needed to generate monopole magnetic field, the accretion disk would be un-necessary.

   Note that at elementary particle the magnetic flux tubes at partonic 2-surfaces satisfies self-duality condition as a boundary condition. Since the flux lines are closed, the simplest elementary particle like entity must involve two wormhole contacts with Euclidian signature of metric through which the magnetic flux flows between space-time sheets with Minkowskian signature flows. Also astrophysical objects could be connected by monopole flux tubes mediating gravitational interaction. If the flux is self-dual, it must be small since the electric charges involve are small albeit predicted to be non-vanishing in TGD framework.

4. Penrose process (see `http://tinyurl.com/ybovomcb`) allows a transfer of energy from rotating Kerr blackhole (see Appendix). This is due to the very special properties of ergosphere (see Appendix), whose boundaries are defined by the condition $g_{tt} = 0$. Blandford-Znajek process [B2] (see `http://tinyurl.com/zlwgwzc`) allows a transfer of energy and angular momentum with the mediation of magnetic field and it has been proposed that this mechanism entangling the flux lines could serve as a mechanism of energy and angular momentum transfer quasars. In this case the magnetic field is external magnetic field rather than inherent to blackhole. Recall that Kerr-Newman solution corresponds to magnetic quadrupole with monopolar $1/r^2$ radial dependence and cannot describe the situation in which magnetic field is dipole or even monopole type.

   In TGD framework the decay of cosmic strings to particles analogous to the decay of inflaton vacuum energy to particles would generate beams in the direction of string like object. This mechanism for quasar would predict that quasars can apparently disappear as the string and thus beam changes its direction and ceases to be directed to Earth. Quite recently, this kind of mysterious disappearance of quasar has been seen (see `http://tinyurl.com/zgbuolt`).

5. One could criticize the assumption that monopolar Kähler magnetic flux tubes mediate the gravitational field. One can in fact consider an alternative. The twistor lift of the Kähler action [L3] describes the dynamics of twistor spaces of space-time surfaces as 6- surfaces in the product of the 6-D twistor spaces of M^4 and CP_2, and dimensionally reduces to Kähler action involving the analog of cosmological term and possibly also the M^4 analog of Kähler action. This approach explains Planck length as the radius of the 2-sphere associated as fiber with M^4 twistor space. The extremely small value of cosmological constant in the recent cosmology reduces to the extremely large value of Kähler coupling strength associated with M^4 twistor part reducing to a volume term coming from S^2 part of Kähler form and possibly also M^4 analog of Kähler action.

   Cosmological constant would be analogous to critical temperature and has a spectrum coming as inverse square of p-adic length scale and its sign is predicted correctly. One must assign to M^4 twistor space a self-dual Kähler form and its M^4 projection could (but need not) appear also in the dimensionally reduced Kähler action. The Kähler form for a causal diamond would be naturally radial self-dual monopole field - I have considered this possibly earlier but gave it up. One can ask whether the magnetic monopole flux assigned with flux tubes could correspond to M^4 part of Kähler form or whether the two induced Kähler forms could have same flux tubes.

Clearly, LIGO could mean also a new era in the theory of gravitation. The basic problem of GRT description of blackholes relates to the classical conservation laws and it becomes especially acute in the non-stationary situation represented by a merger. Post-Newtonian approximation is more than a calculational tool since it brings in conservation laws from Newtonian mechanics and fixes the coordinate system used to that assignable to empty Minkowski space. Further observations about blackhole mergers might force to ask whether Post-Newtonian approximation actually feeds in the idea that space-time is surface in imbedding space. If the mergers are accompanied by gamma ray bursts as a rule, one is forced to challenge the notion of blackhole and GRT itself.

3.3 Does GW150914 force to modify the views about formation of binary blackhole systems?

The considerations below were inspired by a popular article (see `http://tinyurl.com/hhvejqf`) related to the discovery of gravitational radiation in the formation of blackhole from two unexpectedly massive blackholes.

LIGO has hitherto detected two events in which the formation of blackhole as fusion of two blackholes has generated a detectable burst of gravitational radiation. The expected masses for the stars of the binary are typically around 10 solar masses. The later event involve a pair with masses of 8 and 14 solar masses marginally consistent with the expectation. The first event GW150914 involves masses of about 30 solar masses. This looks like a problem since blackhole formation is believed to be preceded via a formation of a red super giant and supernova and in this events star loses a large fraction of its mass.

The standard story evolution of binary to a pair of blackholes would go as follows.

1. In the beginning the stars involved have masses in the range 10-30 solar masses. The first star runs out of the hydrogen fuel in its core and starts to burn hydrogen around the helium core. In this step it puffs up much of the hydrogen at its surface layers forming a red supergiant. The nuclear fusion proceeds in the core until iron core is formed and fusion cannot continue anymore. The first star collapses to a super nova and a lot of mass is thrown out (conservation of momentum forces this).

2. Second star sucks much of the hydrogen after the formation of red supergiant. The core of the first star eventually collapses into a black hole. The stars gradually end end up close to each other. As the second star turns into a supergiant it engulfs its companion inside a common hydrogen envelope. The stars end up even closer to each other and the envelope is lost into space. Eventually the core of also second star collapses into a black hole. The two black holes finally merge together. The model predicts that due to the mass losses the masses of companions of the binary are not much higher than 10 solar masses. This is the problem.

Selma de Mink (see `http://tinyurl.com/zgdhr97`) has proposed a new kind of story about the formation of blackholes from the stars of a binary.

1. The story begins with two very massive stars rotating around each other extremely rapidly and so close together than they become tidally locked. They are like tango dancers. Both dancers would spin around their own axis in the same direction as they spin with respect to each other. This spinning would stir the stars and make them homogenous. Nuclear fusion would continue in the entire volume of the star rather in the core only. Stars would never run out of fuel and throw away they hydrogen layers. Therefore the resulting blackhole would be much more massive. This story would apply only to binaries.

2. The simulations of the homogenous model however have difficulties with more conventional binaries such as the blackhole of the second LIGO signal. Second problem is that the blackholes forming GW150914 have very low spins if any. The proposed explanation would in terms of dance metaphor.

   Strong magnetic fields are present forcing the matter to flow near to the magnetic poles. The effect would be similar to that when figure skater stretches her arms to increase the moment of inertia in spin direction so that the spinning rate slows down by angular momentum conservation. This requires that the direction of the dipole differs from the axis of rotation considerably. Otherwise the spinning rate increases since moment of inertia is reduced: this is how the dancer develops the pirouette. The naive expectation is that the directions of the magnetic and rotation axis are near to each other.

What kind of story would TGD suggest?

1. The additional actor in this story is dark matter identified as large $h_{eff} = h_{gr}$ phases with $\hbar_{gr} = GMm/v_0$, where $v_0/c <$ has dimensions of velocity: ($c = 1$ is assumed for convenience) [K8, K6]. M is the large mass and m a small mass, say mass of elementary particle. The parameter v_0 could be proportional to a typical rotational velocity in the system with universal coefficient.

   The crucial point is that the gravitational Compton length $\Lambda_{gr} = \hbar_{gr}/m = GM/v_0$ of the particle does not depend on its mass and for $v_0 < c/2$ is larger than Schwartschild radius $r_S = 2GM$. For $v_0 > c/2$ the dark particles can reside inside blackhole.

2. Could dark matter be involved with the formation of very massive blackholes in TGD framework? In particular, could the transformation of dark matter to ordinary matter devoured by the blackhole or ending as such to blackhole as such help to explain the large mass of GW150914?

   I have written already earlier about a related problem. If dark matter were sucked by blackholes the amount of dark matter should be much smaller in the recent Universe and it would look very different. TGD inspired proposal is that the dark matter is dark in TGD sense and has large value of Planck constant $h_{eff} = n \times h = h_{gr}$ implying that the dark Compton length for particle with mass m is given by $\Lambda = \hbar_{gr}/m = GM/v_0 = r_S/2v_0$. Λ_{gr} is larger than the value of blackhole horizon radius for $v_0/c < 1/2$ so that the dark matter remains outside the blackhole unless it suffers a phase transition to ordinary matter.

   For $v_0/c > 1/2$ dark matter can be regarded as being inside blackhole or having transformed to ordinary matter. Also the ordinary matter inside r_S could transform to dark matter. For $v_0/c = 1/2$ for which $\Lambda = r_S$ holds true and one might say that dark matter resides at the surface of the blackhole.

3. What could happen in blackhole binaries? Could the phase transition of dark matter to ordinary matter take place or could dark matter reside inside blackhole for $v_0/c \geq 1/2$? This would suggest large spin at the surface of blackhole. Note that the angular momenta of dark matter - possibly at the surface of blackhole - and ordinary matter in the interior could cancel each other.

   The GRT based model GW150914 has a parameter with dimensions of velocity very near to c and the earlier argument leads to the proposal that it approaches its maximal value meaning that Λ approaches $r_S/2$. Already $\Lambda = r_S$ allows to regard dark matter as part of blackhole: dark matter would reside at the surface of blackhole. The additional dark matter contribution could explain the large mass of GW150914 without giving up the standard view about how stars evolve.

4. Do blackholes of the binary dance now? If the gravitational Compton length $\Lambda_{gr} = GM/v_0$ of dark matter particles are so large that the other blackhole is contained within the sphere of radius Λ_{gr}, one might expect that they form single quantum system. This would favor v_0/c considerably smaller than $v_0/c = 1/2$. Tidal locking could take place for the ordinary matter favoring parallel spins. For dark matter antiparallel spins would be favored by vortex analogy (hydrodynamical vortices with opposite spins are attracted).

The more one thinks about the situation, the clearer it becomes that angular momentum transfer is the key problem. The following two mechanisms come in mind in TGD framework.

1. Could magnetic fields explain the low spin of the components of GW150914? In TGD based model for blackhole formation magnetic fields are in a key role. Quite generally, gravitational interactions would be mediated by gravitons propagating along magnetic flux tubes. Sunspot

phenomenon in Sun involves twisting of the flux tubes of the magnetic field and with 11 year period reconnections of flux tubes resolve the twisting: this involves loss of angular momentum. Something similar is expected now: dark photons, gravitons, and possibly also other parts at magnetic flux tubes take part of the angular momentum of a rotating blackhole (or star). The gamma ray pulse observed by Fermi telescope assigned to GW150914 could be associated with this un-twisting sending angular momentum of twisted flux tubes out of the system. This process could transfer the spin of the star out of the system and produce a slowly spinning blackhole. Same process could have taken place for the component blackholes and explain why their spins are so small.

2. The development of ideas about the formation of galaxies and stars tangles of long cosmic strings [L8, L10, L9] occurred after writing of the first paragraph allow to formulate the problem in a more general manner. In standard framework it is difficult to understand how very massive blackholes are possible at all. During the formation of blackhole the radius decreases and the star should throw out a lot of angular momentum to avoid too high spinning velocity in the collapse. This can be achieved by throwing out mass but this makes heavy blackholes impossible.

3. Can TGD provide a solution of this problem? Suppose that both galaxies and stars are tangles along long cosmic strings locally thickened to monopole flux tubes carrying dark matter and energy in TGD sense Long flux tube would provide new degrees of freedom. Could the angular momentum of collapsing star consisting of ordinary matter be transferred from the star to the cosmic string/flux tube without large loss of stellar mass.

   Suppose that one has instead of single monopole flux tube a pair of flux tubes (flux tubes would combine to form a closed flux tube) forming a rotating helical structure. This structure could store the angular momentum to its rotation. Also the radiation and particles travelling around these helical flux tubes could take away part of the angular momentum but flux tubes themselves as TGD counterparts of galactic dark matter could do the main job. Heavy blackholes would be a direct signature for energy and angular mmentum transfer between ordinary matter and galactic dark matter in TGD sense.

3.4 Gravitational Waves from Black Hole Megamergers Are Weaker Than Predicted

Few months after LIGO results there was an interesting popular article in Scientific American with title "Gravitational Waves from Black Hole Megamergers Are Weaker Than Predicted" (see `http://tinyurl.com/j7ckmdw`). The article told about the failure to find support for the effects of gravitational waves from the fusion of supermassive blackholes. The fusions of supermassive blackholes generate gravitational radiation. These collisions would be scaled up versions of the LIGO event.

Supermassive blackholes in galactic centers are by statistical arguments expected to fuse in the collisions of galaxies so often that the generated gravitational radiation produces a detectable hum. This should produce a background hum which should be seen as a jitter for the arrival times of photons of radiation from pulsars. This jitter is same for all pulsars and therefore is expected to be detectable as kind of "hum" defined by gravitational radiation at low frequencies. The frequencies happen to be audible frequencies. For the past decade, scientists with the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) collaboration tried to detect this constant "hum" of low-frequency gravitational waves [E2] (see `http://tinyurl.com/y98gbagh`). The outcome is negative and one should explain why this is the case.

I do not know how much evidence there exists for nearby collisions of galaxies in which fusion of galactic supermassive blackholes really take place. What would TGD suggest? For year ago I would have considered an explanation in terms of dark gravitons with lower detection rate but after the revision of the model for the detection of gravitational waves forced by LIGO discovery the following explanation looks more plausible.

1. In TGD Universe galaxies could be like pearls in necklace carrying dark magnetic energy identifiable as dark matter. This explains galactic rotation curves correctly $1/\rho$ force in

plane orthogonal to the long cosmic string (in TGD sense) defining the necklace gives constant velocity spectrum plus free motion along string: this prediction distinguishes TGD from the competing models. Halo is not spherical since stars are in free motion along cosmic string. The galactic dark matter is identified as dark energy in turn identifiable as magnetic energy of long cosmic string. There is a considerable evidence for these necklaces and this model is one of the oldest parts of TGD inspired astrophysics and cosmology [K2, K9].

2. Galaxies as vehicles moving along cosmic highways defined by long cosmic strings is more dynamical metaphor than pearls in necklace and better in recent context. The dominating interaction would be the gravitational interaction keeping the galaxy at highway and might make fusion of galactic blackholes a rare process.

This model allows to consider the possibility that the fusions of galactic super-massive blackholes are much rarer than expected in the standard model.

1. The gravitational interaction between galaxies at separate highways passing near each other would be secondary interaction and galaxies would pass each other without anything dramatic occurring.

2. If the highways intersect each other the galaxies could collide with each other if the timing is correct but this would be a rare event. This is like two vehicles arriving a crossing simultaneously. In fact, I wrote for a couple of years ago about the possibility that Milky Way could have resulted as the intersection of two cosmic highways (or as a result of cosmic traffic accident).

3. If the galaxies are moving in opposite directions along the *same* highway, the situation changes and a fusion of galactic nuclei in head on collision is unavoidable. It is difficult to say how often this kind of events occur: it could occur that galaxies have after sufficiently many collisions "learned" to move in the same direction and define analog of hydrodynamical flow. A cosmic flow has been observed in "too" long scales and could correspond to a coherent flow along cosmic string.

3.5 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 blackhole 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 [E6] (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 [L5, L7].

1. The simplest possibility allowed by TGD [L7] 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 [K1] (low energy nuclear reactions (LENR) is less misleading term) and also in TGD inspired biology (there is evidence for bio-fusion) as Pollack effect [L1], 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 [K1]. 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 [K10, K5]. 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) [L6] [K1]. 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 [L7]). 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.

3.6 Some comments about GW170817

The observation of GW170817 [E5] (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) [L6] (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 have arrived after 2846 hours making 118 days (day=24 hours). 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 Question" (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)) [L6]. 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.

3.7 LIGO: no evidence for cosmic strings

LIGO has reported [E1] (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.

3.7.1 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.

3.7.2 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.

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.

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.

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.

3.8 LIGO challenges the views about formation of neutron stars and their collisions

The observation of gravitational radiation by LIGO allowing interpretation as fusion of two neutron stars has challenged the views about neutrons stars and star formation: see the popular article in Quanta Magazine (`http://tinyurl.com/tqwnrne`) about the work of Enrico Ramirez-Ruiz and colleagues (`https://arxiv.org/abs/2001.04502`). Single neutron star collision with exceptional characteristics as such is not enough for revolution. One can however ask what it could mean if this event is not a rare statistical fluctuation but business as usual.

1. The pair has too high total mass: only 10 per cent of stars are estimated to be massive enough to make so massive neutron stars. Something in the models for star formation might be badly wrong.

2. Also the models for the formation of neutron star pairs are unable to explain why the abundance of so massive pairs would be so high as LIGO would predict. There could be something wrong also in the models for the collisions of stellar objects.

TGD provides several new physics elements to the possible model.

1. Galaxies, stars, even planets are tangles in cosmic strings carrying dark energy and (also galactic) dark matter and thickened to monopole flux tubes not possible in standard gauge theories. This leads to a general model of stars and of final states of stars as flux tube tangles as spaghettis filling the volume and thus maximally dense. One obtains nice quantitative predictions plus a generalization of the notion of blackhole like entity (BHE) so that all final

states of stars are BHEs: BHEs would be characterizied by the quantized thickness of the flux tube in question.

Also a TGD based modification of the view about nuclear fusion required by a 10 year old nuclear physics anomaly and "cold fusion" is involved solving a long list of nuclear physics related anomalies (`http://tinyurl.com/tkkyyd2`).

2. Collision of stellar objects producing blackholes can occur much more often than expected. Suppose one has two long flux tube portions going very near to each other: they could be portions of the same closed flux tube or of two separate flux tubes. The situation would be this for instance in galactic nuclei of spiral galaxies (`http://tinyurl.com/sg9c4sd`).

   The colliding stellar objects correspond to flux tube tangles moving along them. Since the stellar objects are forced to move along these cosmic highways, their collisions as cosmic traffic accidents become much more frequent than for randomly moving objects in ordinary cosmology. The cosmic highways force them to come near to each other at crossings and gravitational attraction strengthens this tendency.

   Situation would be analogous in bio-chemistry: bio-catalysis would involve flux tubes connecting reactants and the reduction of effective Planck constants would reduce flux tube length and bring the reactants together and liberating the energy to overcome the potential wall making reaction extremely slow in ordinary chemistry.

   Already the high rate of collisions might allow to understand why the first collision of neutron stars observed by LIGO was that for unexpectedly high total mass.

This model does not yet answer the question why so heavy neutron stars are possible at all. Also the fusion of "too heavy" blackholes has been observed by LIGO [L4] (`http://tinyurl.com/y79yqw6q`). Thus the blackhole formation from a neutron star pair with unexpectedly high combined mass supports the expecation that "too" heavy stars are a rule rather than exception.

1. The problem is that during the formation of blackhole or neutron the radius of the star decreases and the star should throw out a lot of angular momentum to avoid too high spinning velocity in the collapse. This can be achieved by throwing out mass but this makes heavy blackholes and neutron stars impossible.

2. Can TGD provide a solution of this problem? Suppose that both galaxies and stars are tangles along long cosmic strings locally thickened to monopole flux tubes carrying dark matter and energy in TGD sense Long flux tube would provide new degrees of freedom. Could the angular momentum of collapsing star consisting of ordinary matter be transferred from the star to the cosmic string/flux tube without large loss of stellar mass.

   Suppose that one has single monopole flux tube or a pair of monopole flux tubes as analog of DNA double strand (flux tubes would combine to form a closed flux tube) forming a rotating helical structure. This structure could store the angular momentum to its rotation. Also the radiation and particles travelling around these helical flux tubes could take away part of the angular momentum but flux tubes themselves as TGD counterparts of galactic dark matter could do the main job. Heavy blackholes would be a direct signature for energy and angular mmentum transfer between ordinary matter and galactic dark matter in TGD sense.

4 Appendix: Some details about rotating and charged blackholes

Kerr blackhole is rotating and Kerr-Newman blackhole possess also charge so that it could describe blackhole with magnetic field generated by the rotating charge. Schwartschild-Nordström blackhole allows imbedding to $H = M^4 \times CP_2$ but the dimension of $M^4 \times CP_2$ is probably too low to allow imbedding of rotating blackholes and certainly the Kerr-Newman blackhole is non-imbeddable. Kerr metrics could however make sense as GRT approximation to a description of rotating and charged system in terms of many-sheeted space-time.

I received from Ulla a link to slides explaining rather clearly the basic facts about rotating blackholes (see `http://tinyurl.com/qzukqhs`): unfortunately there is a mistake in the formula for the line element of Kerr metric. Also Wikipedia article (see http://tinyurl.com/ya9dnt6t) gives a nice summary about Kerr-Newman metric [B1, B3]. Another further link was to an article explaining Blandford-Znajek process possibly allowing to extract energy and angular momentum from a rotating blackhole in external magnetic field (see http://tinyurl.com/zlwgwzc).

This motivated to collect facts about Kerr-Newman blackholes from TGD view point.

1. Kerr and Kerr-Newman blackholes are easier to represent in Boyer-Lindqist coordinate system related to spherical coordinates in very simple manner:

$$x = \rho sin(\theta)cos(\phi) \ , \quad y = \rho sin(\theta)sin(\phi) \ , \quad z = rcos(\theta) \ , \quad \rho = \sqrt{a^2+r^2} \ . \tag{4.1}$$

One can say that there is a hole of radius $asin(\theta)$. Parameter $a = J/M$ defines the maximal radius of the hole.

2. Kerr-Newman metric(signature $(1,-1,-1,-1)$) is given by

$$ds^2 = -(\frac{dr^2}{\Delta} + d\theta^2)\rho^2 + (dt - asin^2\theta d\phi)^2\frac{\Delta}{\rho^2} - (r^2+a^2)d\phi - adt)^2\frac{sin^2(\theta)}{\rho^2} \ , \tag{4.2}$$

where various auxiliary variables and parameters are defined as

$$\begin{array}{lll} \rho^2 = r^2 + a^2cos^2(\theta) \ , & \Delta = r^2 - r_sr + a^2 + r_Q^2 \ , & \\ r_S = 2GM \ , & a = \frac{J}{M} \ , & r_Q^2 = Q^2G \ . \end{array} \tag{4.3}$$

For $Q = 0$ one obtains Kerr metric and for $(J = 0, Q = 0)$ one obtains Kerr metric and for $J = 0$ Scwartschild metric.

Kerr-Newman metric has more complex singularities than Scwartschild metric. The singularities come from $\rho^2 = 0$ and $\Delta = 0$ as is easy to see by inspecting the metric.

1. The first singularity correspond to vanishing of Δ and gives

$$r_\pm = \frac{1}{2}(r_S^2 \pm \sqrt{r_S^2 - a^2 - r_Q^2}) \ .$$

If r is replaced with ρ these spheres look like ellipsoids. The larger ellipsoid is within Schwartschild radius. The condition that $r_\pm$is real implies

$$J^2 + GM^2Q^2 \leq G^2M^4 \ . \tag{4.4}$$

For $Q = 0$ this gives

$$J \leq GM^2 \ . \tag{4.5}$$

There is a possibly interesting connection with the notion of gravitational Planck constant. It is defined originally for flux tubes connecting systems with masses M and m as $\hbar_{gr} = GMm/v_0$, $v_0/c < 1$ but could be defined also for the flux tubes of dipole field associated with mass M as $\hbar_{gr} = GM^2/2\pi v_0$. This would give $J \leq 2\pi(v_0/c)\hbar_{gr}$. If dark dark spin is quantized as usual: $J = j\hbar_{gr}$, $j = 1, 1/2, 1, ...$ this would give $2\pi(v_0/c)$ giving $j \leq 6$ and $v_0/c \geq 1/4\pi$. One must take this with extreme caution since there is evidence that fractionization of quantum numbers takes place for large $h_{eff} = n$: in this case one cannot regard h_{gr} as unit of angular momentum.

2. Second singularity correspond to $\rho^2 = 0$ for which $r = 0$ and $\theta = \pi/2$ holds: one obtains what looks like a ring at equator. For Kerr metric this is indeed a circle with circumference $2\pi a$ as the inspection of line-element show ($g_{\phi\phi} \to a^2$).

3. For Kerr-Newman metric $g_{\phi\phi}$ changes sign and becomes infinite so that the angle coordinate becomes time like coordinate. The circumference of the circle would be infinite. One has closed time-like geodesic of infinite length and more of them with finite length in the immediate vicinity of the ring. This physically very strange and even more strange from TGD view point if one thinks of possible (even approximate) imbeddings into H. This is what one obtains for the line elements given in Wikipediaandalso in [B3]http://tinyurl.com/y7r2gdvn. Since the form depending on Δ appears in two references (in second article Newman himself is second author!), it seems that it must be correct.

4. The condition $g_{tt} = 0$ defines the boundaries of ergosphere as

$$r_{es,\pm} = \frac{1}{2}(r_S \pm \sqrt{r_S^2 - a^2cos^2(\theta)}) \ . \tag{4.6}$$

   The larger ellipsoid defining the outer boundary of the ergosphere contains the horizons and and has r_S as the maximal value of radius. For Kerr metric he lower boundary corresponds to smaller ellipsoid for Kerr metric and contains the ring singularity.

   Inside ergosphere only space-like geodesics are possible so that everything - also test particles - moves with superluminal velocity. One can perhaps say that this space-time region is geodesically Euclidian. Also the hypothesis that Equivalence Principle in the sense that one can describe the local physics using QFT in Minkowski space fails since massive and massless on mass-shell states do not exist: this is an important objection against the idea that blackhole horizon has no physical significance because the curvature is small. The geodesics are light-like at the surface of ergosphere. These observations support the TGD proposal that blackhole interior has actually Euclidian signature of (induced) metric in TGD framework and horizon is the light-like surface at which the signature changes and the dimension of the tangent degenerates $D = 3$. This conforms also with the strong form of holography stating these light-like surfaces can be regarded as carriers of various quantum numbers.

   Even outside the ergosphere non-vanishing of $g_{t\phi}$ induces so called frame dragging: one can say that blackhole forces the surrounding space-time to rotate with it. For instance, test particle rotating in opposite direction eventually turns to rotate in the same direction as blackhole.

Could Kerr-Newman metric represent a blackhole with magnetic field as the non-vanishing charge and rotation suggests?

1. From Wikipedia article one finds the explicit expression for the gauge potential and there is indeed magnetic field represent. $J_{\theta\phi}$ approaches asymptotically to $sin(\theta)cos(\theta)$, which corresponds to quadrupole rather than monopole: on the other hand, the radial dependence is $1/r^2$ rather than $1/r^4$ so that the behaviour looks weird. Locally the flux is constant so that in TGD framework one could consider the possibility that the flux is mediated along flux tubes, which return back with the direction of flux and angular density of flux tubes depending on θ. The very strange behavior at ring singularity however suggests that this solution is not interesting even at the GRT limit of TGD.

2. Penrose process allows a transfer of energy from rotating blackhole. This is due to the very special properties of ergosphere, whose boundaries are defined by the condition $g_{tt} = 0$. Blandford-Znajek process [B2] (see http://tinyurl.com/zlwgwzc) allows a transfer of energy and angular momentum with the mediation of magnetic field and it has been proposed that this mechanism entangling the flux lines could serve as a mechanism of energy and angular momentum transfer quasars. In this case the magnetic field is external magnetic field rather than inherent to blackhole.

In TGD framework the decay of cosmic strings to particles analogous to the decay of inflaton vacuum energy to particles would generate beams in the direction of string like object. This mechanism for quasar would predict that quasars can apparently disappear as the string and thus beam changes its direction and ceases to be directed to Earth. Quite recently, this kind of mysterious disappearance of quasar has been seen.

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