Cosmic Strings

M. Pitkänen,

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Email: matpitka6@gmail.com.
http://tgdtheory.com/public_html/.
Postal address: Rinnekatu 2-4 A 8, 03620, Karkkila, Finland. ORCID: 0000-0002-8051-4364.

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Abstract

Cosmic strings belong to the basic extremals of the Kähler action. The upper bound for string tension of the cosmic strings is $T \simeq .5 \times 10^{-6}/G$ and in the same range as the string tension of GUT strings and this makes them very interesting cosmologically although TGD cosmic strings have otherwise practically nothing to do with their GUT counterparts.

1. Basic ideas

The understanding of cosmic strings has developed only slowly and has required dramatic modifications of existing views.

1. Zero energy ontology implies that the energy and all quantum numbers of the Universe vanishes and physical states are zero energy states decomposing into pairs of positive and negative energy states localizable to the light-like boundaries of causal diamonds defined as intersections of future and past directed light-cones. Positive energy ontology is a good approximation under certain assumptions.
2. Dark matter hierarchy whose levels are labeled by gigantic values of gravitational Planck constant associated with dark matter is second essential piece of the picture.
3. The second variation of Kähler action vanishes for preferred extremals - at least the second variations associated with dynamical symmetries. This guarantees that Noether currents assignable to the Kähler-Dirac action are conserved. The properties of the preferred extremals suggest a dimensional reduction providing formulations of quantum TGD in terms of possibly dual slicings of space-time surface by string word sheets and partonic 2-surfaces. The localization of the modes of the Kähler-Dirac equation to 2-D surfaces - string world sheets and possibly partonic 2-surfaces) suggests something similar although ot might be that both kind of objects are necessary for a full description.
4. GRT limit of can be understood as an outcome of the replacement of sheets of the many-sheeted space-time with single sheet endowed with effective metric given by the sum of Minkowski metric and deviations of the induced metrics of space-time sheets from Minkowski metric. Gauge theory limit can be understood in an analogous manner. Equivalence Principle in Einsteinian sense follows from Poincare invariance of TGD. The additional assumption made before a real understanding of GRT limit was that the the most important GRT space-times can be represented as vacuum extremals of Kähler action. This assumption can be of course questioned.
5. The basic question whether one can model the exterior region of the topologically condensed cosmic string using General Relativity. The exterior metric of the cosmic string corresponds to a small deformation of a vacuum extremal assuming the identification of the most important GRT space-times as vacuum extremals of Kähler action. The angular defect and surplus associated with the exterior metrics extremizing curvature scalar can be much smaller than assuming vacuum Einstein's equations. The conjecture is that the exterior metric of galactic string conforms with the Newtonian intuitions and thus explains the constant velocity spectrum of distant stars if one assumes that galaxies are organized to linear structures along long strings like pearls in a necklace.

2. Critical and over-critical cosmologies involve accelerated cosmic expansion

In TGD framework critical and over-critical cosmologies are unique apart from single parameter telling their duration and predict the recently discovered accelerated cosmic expansion. Critical cosmologies are naturally associated with quantum critical phase transitions involving the change of gravitational Planck constant. A natural candidate for such a transition is the increase of the size of a large void as galactic strings have been driven to its boundary. During the phase transitions connecting two stationary cosmologies (extremals of curvature scalar) also determined apart from single parameter, accelerated expansion is predicted to occur. These transitions are completely analogous to quantum transitions at atomic level.

The proposed microscopic model predicts that the TGD counterpart of the quantity $\rho + 3p$ for cosmic strings is negative during the phase transition which implies accelerated expansion. Dark energy is replaced in TGD framework with dark matter indeed predicted by TGD and its fraction is .74 as in standard scenario. Cosmological constant thus characterizes phenomenologically the density of dark matter rather than energy in TGD Universe.

The sizes of large voids stay constant during stationary periods which means that also cosmological constant is piecewise constant. p-Adic length fractality predicts that Λ scales as $1/L^2(k)$ as a function of the p-adic scale characterizing the space-time sheet of void. The

order of magnitude for the recent value of the cosmological constant comes out correctly. The gravitational energy density described by the cosmological constant is identifiable as that associated with topologically condensed cosmic strings and of magnetic flux tubes to which they are gradually transformed during cosmological evolution.

3. Cosmic strings and generation of structures

1. In zero energy ontology cosmic strings must be created from vacuum as zero energy states consisting of pairs of strings with opposite time orientation and inertial energy.
2. The counterpart of Hawking radiation provides a mechanism by which cosmic strings can generate ordinary matter. The splitting of cosmic strings followed by a "burning" of the string ends provides a second manner to generate visible matter. Matter-antimatter symmetry would result if antimatter is inside cosmic strings and matter in the exterior region. A justification for CP asymmetry comes from basic quantum TGD. One can add to Kähler function of the WCW an imaginary part defined by instanton term $J \wedge J$. This term does not affect Kähler metric but implies CP breaking.
3. Zero energy ontology has deep implications for the cosmic and ultimately also for biological evolution (magnetic flux tubes paly a fundamental role in TGD inspired biology and cosmic strings are limiting cases of them). The arrows of geometric time are opposite for the strings and also for positive energy matter and negative energy antimatter. This implies a competition between two dissipative time developments proceeding in different directions of geometric time and looking self-organization and even self-assembly from the point of view of each other. This resolves paradoxes created by gravitational self-organization contra second law of thermodynamics. So called super-symplectic matter at cosmic strings implies large p-adic entropy resolves the well-known entropy paradox.
4. p-Adic fractality and simple quantitative observations lead to the hypothesis that cosmic strings are responsible for the evolution of astrophysical structures in a very wide length scale range. Large voids with size of order 10^8 light years can be seen as structures cosmic strings wound around the boundaries of the void. Galaxies correspond to same structure with smaller size and linked around the supra-galactic strings. This conforms with the finding that galaxies tend to be grouped along linear structures. Simple quantitative estimates show that even stars and planets could be seen as structures formed around cosmic strings of appropriate size. Thus Universe could be seen as fractal cosmic necklace consisting of cosmic strings linked like pearls around longer cosmic strings linked like...

4. Cosmic strings, gamma ray bursts, and supernovae

During year 2003 two important findings related to cosmic strings were made.

1. A correlation between supernovae and gamma ray bursts was observed.
2. Evidence that some unknown particles of mass $m \simeq 2m_e$ and decaying to gamma rays and/or electron positron pairs annihilating immediately serve as signatures of dark matter. These findings challenge the identification of cosmic strings and/or their decay products as dark matter, and also the idea that gamma ray bursts correspond to cosmic fire crackers formed by the decaying ends of cosmic strings.

This forces the updating of the more than decade old rough vision about topologically condensed cosmic strings and about gamma ray bursts described in this chapter. According to the updated model, cosmic strings transform in topological condensation to magnetic flux tubes about which they represent a limiting case. Primordial magnetic flux tubes forming ferromagnet like structures become seeds for gravitational condensation leading to the formation of stars and galaxies. The TGD based model for the asymptotic state of a rotating star as dynamo leads to the identification of the predicted magnetic flux tube at the rotation axis of the star as Z^0 magnetic flux tube of primordial origin. Besides Z^0 magnetic flux tube structure also magnetic flux tube structure exists at different space-time sheet but is in general not parallel to the Z^0 magnetic structure. This structure cannot have primordial origin (the magnetic field of star can even flip its polarity).

The flow of matter along Z^0 magnetic (rotation) axis generates synchrotron radiation, which escapes as a precisely targeted beam along magnetic axis and leaves the star. The identification is as the rotating light beam associated with ordinary neutron stars. During the core collapse leading to the supernova this beam becomes gamma ray burst. The mechanism is very much analogous to the squeezing of the tooth paste from the tube. The fact that all nuclei are fully ionized Z^0 ions, the Z^0 charge unbalance caused by the ejection of neutrinos, and the radial compression make the effect extremely strong so that there are hopes to understand the observed incredibly high polarization of 80 ± 20 per cent.

The W fields experienced by fundamental fermions at 2-D surfaces at which they are localized vanish by the well-definedness of em charge, and one can also require that Z^0 fields vanish at least above weak scale. The vanishing of effective weak fields is an obvious objection against the model unless one allows the possibility of large values of $h_{eff} = n \times h$ strongly suggested by the identification $h_{eff} = h_{gr}$, where $h_{gr}GMm/v_0$ is the gravitational Planck constant inspired by Nottale's considerations: here M and m would correspond to masses of supernova and of microscopic system.

TGD suggests the identification of particles of mass $m \simeq 2m_e$ accompanying dark matter as lepto-pions formed by color excited leptons, and topologically condensed at magnetic flux tubes having thickness of about lepto-pion Compton length. Lepto-pions would serve as signatures of dark matter whereas dark matter itself would correspond to the magnetic energy of topologically condensed cosmic strings transformed to magnetic flux tubes.

1 Introduction

Cosmic strings belong to the basic extremals of the Kähler action. These cosmic strings have nothing to do with the cosmic strings of GUTS [E44] but their string tension $T \simeq .52 \times 10^{-6}/G$ happens to be in the same range as that for the GUT strings and this makes them very interesting cosmologically. Indeed, string like objects play a fundamental role in TGD inspired cosmology and also provide TGD based models for the galaxy formation, galactic dark matter, and for the generation of the large voids. Therefore the study of the properties of cosmic strings deserves a separate chapter.

The progress in the understanding of the physics of cosmic strings has been slow due to the difficult interpretational problems.

1. Zero energy ontology implies that the energy and all quantum numbers of the Universe vanishes and physical states are zero energy states decomposing into pairs of positive and negative energy states localizable to the light-like boundaries of causal diamonds defined as intersections of future and past directed light-cones. Positive energy ontology is a good approximation under certain assumptions.

2. Dark matter hierarchy whose levels are labelled by gigantic values of gravitational Planck constant associated with dark matter is second essential piece of the picture.

3. The second variation of Kähler action vanishes for preferred extremals - at least the second variations associated with dynamical symmetries. This guarantees that Noether currents assignable to the Kähler-Dirac action are conserved. The properties of the preferred extremals suggest a dimensional reduction providing formulations of quantum TGD in terms of possibly dual slicings of space-time surface by string word sheets and partonic 2-surfaces. The localization of the modes of the Kähler-Dirac equation to 2-D surfaces - string world sheets and possibly partonic 2-surfaces) suggests something similar although ot might be that both kind of objects are necessary for a full description.

4. It is now clear that GRT space-time as region of Minkowski space with metric differing from flat Minkowski metric slightly follows as an approximation of many-sheeted space-time of TGD and that Equivalence Principle reflects Poincare invariance. Cosmic strings represent something not possible in GRT context. The very early cosmology described in terms of gas of cosmic strings in $M^4_+ \times CP_2$ corresponds to this kind of situation and inflationary period would correspond to a transition to radiation dominated cosmology.

1.1 Various Strings

TGD predicts two basic types of strings.

1. The analogs of hadronic strings correspond to deformations of vacuum extremals carrying non-vanishing induced Kähler fields. p-Adic thermodynamics for super-symplectic quanta

condensed on them with additivity of mass squared yields without further assumptions stringy mass formula. These strings are associated with various fractally scaled up variants of hadron physics.

2. Cosmic strings correspond to homologically non-trivial geodesic sphere of CP_2 (more generally to complex sub-manifolds of CP_2) and have a huge string tension. These strings are expected to have deformations with smaller string tension which look like magnetic flux tubes with finite thickness in M^4 degrees of freedom. The signature of these strings would be the homological non-triviality of the CP_2 projection of the transverse section of the string.

1.2 Correlation Between Super-Novae And Cosmic Strings

During year 2003 two important findings related to cosmic strings were made.

1. A correlation between supernovae and gamma ray bursts was observed.

2. Evidence that some unknown particles of mass $m \simeq 2m_e$ and decaying to gamma rays and/or electron positron pairs annihilating immediately serve as signatures of dark matter. These findings challenge the identification of cosmic strings and/or their decay products as dark matter, and also the idea that gamma ray bursts correspond to cosmic fire crackers formed by the decaying ends of cosmic strings. This forces the updating of the more than decade old rough vision about topologically condensed cosmic strings and about gamma ray bursts described in this chapter (old version is left essentially untouched in order to demonstrate how important the experimental input is for the evolution of ideas).

According to the updated model, cosmic strings transform in topological condensation to magnetic flux tubes about which they represent a limiting case. Primordial magnetic flux tubes forming ferro-magnet like structures become seeds for gravitational condensation leading to the formation of stars and galaxies. The TGD based model for the asymptotic state of a rotating star as dynamo [K16] leads to the identification of the predicted magnetic flux tube at the rotation axis of the star as Z^0 magnetic flux tube of primordial origin (flux tube carries also em field but could carry only Z^0 charge). Besides Z^0 magnetic flux tube structure also magnetic flux tube structure exists at different space-time sheet but is in general not parallel to the Z^0 magnetic structure. This structure cannot have primordial origin (the magnetic field of star can even flip its polarity).

The flow of matter along Z^0 magnetic (rotation) axis generates synchrotron radiation, which escapes as a precisely targeted beam along magnetic axis and leaves the star. The identification is as the rotating light beam associated with ordinary neutron stars. During the core collapse leading to the supernova this beam becomes gamma ray burst. The mechanism is very much analogous to the squeezing of the tooth paste from the tube.

TGD based models of nuclei [K12] and condensed matter [K4] suggests that the nuclei of dense condensed matter develop anomalous color and weak charges coupling to dark weak bosons having Compton length L_w of order atomic size. Also lighter copies of weak bosons can be important in living matter. This weak charge is vacuum screened above L_w and by dark particles below it. Dark neutrinos are good candidates for screening dark particles. The Z^0 charge unbalance caused by the ejection of screening dark neutrinos hinders the gravitational collapse. The strong radial compression amplifies the tooth paste effect in this kind of situation so that there are hopes to understand the observed incredibly high polarization of 80 ± 20 per cent [E20].

TGD suggests the identification of particles of mass $m \simeq 2m_e$ accompanying dark matter as lepto-pions [K15] formed by color excited leptons, and topologically condensed at magnetic flux tubes having thickness of about lepto-pion Compton length. Lepto-pions would serve as signatures of dark matter whereas dark matter itself would correspond to the magnetic energy of topologically condensed cosmic strings transformed to magnetic flux tubes..

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L2].

2 General Vision About Topological Condensation Of Cosmic Strings

In this section the basic properties of free cosmic strings are discussed and a general vision about topological condensation of cosmic strings is proposed. In the later sections the vision is developed at a more quantitative level.

2.1 Free Cosmic Strings

The free cosmic strings correspond to four-surfaces of type $X^2 \times S^2$, where S^2 is the homologically nontrivial geodesic sphere of CP_2 [L1] , [L1] and X^2 is minimal surface in M^4_+. As a matter fact, any complex manifold $Y^2 \subset CP_2$ is possible. In this section, a co-moving cosmic string solution inside the light cone $M^4_+(m)$ associated with a given m point of M^4_+ will be constructed.

Recall that the line element of the light cone in co-moving coordinates inside the light cone is given by

$$ds^2 = da^2 - a^2(\frac{dr^2}{1+r^2} + r^2 d\Omega^2) \ . \quad (2.1)$$

Outside the light cone the line element is given

$$ds^2 = -da^2 - a^2(-\frac{dr^2}{1-r^2} + r^2 d\Omega^2) \ , \quad (2.2)$$

and is obtained from the line element inside the light cone by replacements $a \rightarrow ia$ and $r \rightarrow -ir$.

2.1.1 Simplest solutions

Using the coordinates $(a = \sqrt{(m^0)^2 - r_M^2}, ar = r_M)$ for X^2 the orbit of the cosmic string is given by

$$\begin{aligned} \theta &= \frac{\pi}{2} \ , \\ \phi &= f(r) \ . \end{aligned} \quad (2.3)$$

Inside the light cone the line element of the induced metric of X^2 is given by

$$ds^2 = da^2 - a^2(\frac{1}{1+r^2} + r^2 f_{,r}^2)dr^2 \ . \quad (2.4)$$

The equations stating the minimal surface property of X^2 can be expressed as a differential conservation law for energy or equivalently for the component of the angular momentum in the direction orthogonal to the plane of the string. The conservation of the energy current T^α gives

$$\begin{aligned} T^\alpha_{,\alpha} &= 0 \ , \\ T^\alpha &= T g^{\alpha\beta} m^0_{,\beta}\sqrt{g} \ , \\ T &= \frac{1}{8\alpha_K R^2} \simeq .52 \times 10^{-6}\frac{1}{G} \ . \end{aligned} \quad (2.5)$$

The numerical estimate $TG \simeq .8.9 \times 10^{-6}$ for the string tension is upper bound and corresponds to a situation in which the entire area of S^2 contributes to the tension. It has been obtained using $\alpha_K \simeq 1/137$ and $R^2/G = 2.5 \times 10^7 G$ given by the most recent version of p-adic mass calculations (the earlier estimate was roughly by a factor 1/2 too small due to error in the calculation [K5, K14]). The string tension belongs to the range $TG \in [10^{-6} - 10^{-7}]$ predicted for GUT strings [E44]. WMAP data give the upper bound $TG \in [10^{-6} - 10^{-7}]$, which does not however hold true in the recent case since criticality predicts adiabatic spectrum of perturbations as in the inflationary scenarios.

The non-vanishing components of energy current are given by

$$\begin{aligned} T^a &= TUa \ , \\ T^r &= -T\frac{r}{U} \ , \\ U &= \sqrt{1+r^2(1+r^2)f_{,r}^2} \ . \end{aligned} \tag{2.6}$$

The equations of motion give

$$U = \frac{r}{\sqrt{r^2-r_0^2}} \ , \tag{2.7}$$

or equivalently

$$\phi_{,r} = \frac{r_0}{r\sqrt{(r^2-r_0^2)(1+r^2)}} \ , \tag{2.8}$$

where r_0 is an integration constant to be determined later. Outside the light cone the solution has the form

$$\phi_{,r} = \frac{r_0}{\sqrt{r^2+r_0^2}r\sqrt{1-r^2}} \ . \tag{2.9}$$

In the region inside the light cone, where the conditions

$$r_0 << r << 1 \tag{2.10}$$

hold, the solution has the form

$$\begin{aligned} \phi(r) &\simeq \phi_0 + \frac{v}{r} \ , \\ v &= \frac{r_0}{\sqrt{1+r_0^2}} \ , \end{aligned} \tag{2.11}$$

corresponding to the linearized equations of motion

$$f_{,rr} + \frac{2f_{,r}}{r} = 0 \ , \tag{2.12}$$

obtained most nicely from the angular momentum conservation condition.

2.1.2 Planck2013 bounds for the string tension of string like objects of various kinds

Planc2013 (see `http://tinyurl.com/ydegc4ry`) gives bounds on the string tension of cosmic strings. The bounds depend on the type of string considered: sone can consider Nambu-Goto strings, cosmic strings of gauge theories, string like objects of field theories, etc.... The upper bounds for TG are in the range $10^{-6} - 10^{-7}$.

One cannot of course directly compare these bounds to cosmic strings in TGD sense (not gauge theory strings but primordial 4-D string like objects). In TGD framework the string tension characterizes the density of Kähler magnetic energy of 4-D string like object with 2-D string world sheet as Minkowski space projection.

Cosmic string tension is inversely proportional to the square of CP_2 length scale R and to Kähler coupling strength α_K for which the most recent estimate is as equal to fine structure constant: $\alpha_K \simeq 1/137$. The value of R is fixed by p-adic mass calculations from the conditions that electron mass comes out correctly. The velocity spectrum of distance stars in galaxy gives the same estimate if the gravitational field created by long cosmic string along which galaxies are located like pearls in string, gives an estimate consistent with this value. The estimate (see `http://tinyurl.com/y8wbeo4q`) of cosmic string tension is $TG = 6.9 \times 10^{-7}$ and is therefore in the interval $10^{-6} - 10^{-7}$, where the upper bounds for other string tensions reside.

A comparison with string theory is in order. For Nambu-Goto strings the estimated upper bound for string tension is $GT < 1.5 \times 10^{-7}$ - not a good news since the Nambu-Goto string tension should satisfy $GT = 1$ in the original approach. The same holds true also for superstrings (see `http://tinyurl.com/yb7alzb9`) in the original sense of the word. Therefore the situation is not very promising for superstrings. In fact, it turned out very difficult to find anything concrete about the string tension of superstrings. I however found from web a ten year old estimate estimate (see `http://tinyurl.com/ycs2awy2`) $TG = 1/3000$ for superstring tension involving experimental input. Presumably the Planck 2013 results would lower this estimate by few orders of magnitude.

2.1.3 Cosmic string is stationary in comoving coordinates

In co-moving coordinates (in general the co-moving coordinates of sub-light-cone M^4_+!) the string is stationary. In Minkowski coordinates string rotates with an angular velocity inversely proportional to the distance from the origin

$$\omega \simeq \frac{v}{r_M} \tag{2.13}$$

so that the orbital velocity of the string becomes essentially constant in this region. For very large values of r the orbital velocity of the string vanishes as $1/r$. Outside the light cone the variable r is in the role of time and for a given value of the time variable r strings are straight and one can regard the string as a rigidly rotating straight string in this region.

Inside the light cone, the solution becomes ill defined for the values of r smaller than the critical value r_0. Although the derivative $\phi_{,r}$ becomes infinite at this limit, the limiting value of ϕ is finite so that strings winds through a finite angle. The normal component T^r of the energy momentum current vanishes at $r = r_0$ identically, which means that no energy flows out at the end of the string. The coordinate variable r becomes however bad at $r = r_0$ (string resembles a circle at r_0) and this conclusion must be checked using ϕ as coordinate instead of r. The result is that the normal component of the energy current indeed vanishes.

Field equations are not however satisfied at the end of the string since the normal component of the angular momentum current (in z- direction) is non-vanishing at the boundary and given by

$$J^r = Tr^2a \ . \tag{2.14}$$

This means that the string loses angular momentum through its ends although the angular momentum density of the string is vanishing. The angular momentum lost at moment a is given by

$$J = \frac{Tr^2a^2}{2} = \frac{Tr_M^2}{2} \ . \tag{2.15}$$

This angular momentum is of the same order of magnitude as the angular momentum of a typical galaxy [E45].

In M^4 coordinates singularity corresponds to a disk in the plane of string growing with a constant velocity, when the coordinate m^0 is positive

$$\begin{aligned} r_M &= vm^0 \ , \\ v &= \frac{r_0}{\sqrt{1+r_0^2}} \ . \end{aligned} \tag{2.16}$$

From the expression of the energy density of the string

$$\begin{aligned} T^a &= T\frac{ar}{\sqrt{r^2 - r_0^2}} \ , \\ T &= \frac{1}{8\alpha_K R^2} \ , \end{aligned} \tag{2.17}$$

it is clear that energy density diverges at the singularity.

2.1.4 Energy of the cosmic string

As already noticed, the string tension is by a factor of order 10^{-6} smaller than the critical string tension $T_{cr} = 1/4G$ implying angle deficit of 2π in GRT so that there seems to be no conflict with General Relativity (unlike in the original scenario, in which the CP_2 radius was of order Planck length).

The energy of the string portion ranging from r_0 to r_1 is given by

$$E = T\sqrt{(r_1^2 - r_0^2)a} = T\sqrt{\delta r_M^2} \ . \tag{2.18}$$

It should be noticed that M^4 time development of the string can be regarded as a scaling: each point of the string moves to radial direction with a constant velocity v.

One can calculate the total change of the angle ϕ from the integral

$$\Delta\phi = \sqrt{\frac{r_0^2}{1+r_0^2}} \int_{r_0}^{\infty} dr \frac{1}{r\sqrt{(r^2 - r_0^2)(1+r^2)}} \ . \tag{2.19}$$

The upper bound of this quantity is obtained at the limit $r_0 \rightarrow 0$ and equals to $\Delta\phi = \pi/2$.

2.2 TGD Based Model For Cosmic Strings

The model for cosmic strings has forced to question all cherished assumptions including positive energy ontology, Equivalence Principle, and positivity of gravitational mass. The final outcome turned out to be rather conservative. Zero energy ontology is unavoidable, Equivalence Principle holds true universally but its general relativistic formulation makes sense only in long length scales, and gravitational mass has definite sign for positive/negative energy states. As a matter fact, all problems were created by the failure to realize that the expression of gravitational energy in terms of Einstein's tensor does not hold true in short length scales and must be replaced with the stringy expression resulting naturally by dimensional reduction of quantum TGD to string model like theory [K17, K5, K14]. Later much better understanding of the relationship between TGD and GRT and Equivalence Principle has emerged [K16].

2.2.1 Zero energy ontology and cosmic strings

There are two kinds of cosmic strings: free and topological condensed ones and both are important in TGD inspired cosmology.

1. Free cosmic strings are not absolute minima of the Kähler action (the action has wrong sign). In the original identification of preferred extremals as absolute minima of Kähler action proposed in positive energy ontology this was a problem. In zero energy ontology (ZEO) the preferred extremal property becomes obsolete for deterministic action principle since 3-surfaces correspond to pairs of 3-surfaces at opposite light-like boundaries of causal diamond (CD). This could be the case even in non-deterministic situation applying to Kähler action. The idea about Bohr orbit property as space-time correlate for the correlation of quantum states at opposite boundaries of CD suggests that the members of the pairs of 3-surfaces are not independent but there is a correlation between them expressible as preferred extremal property.

In the new formulation preferred extremals would correspond to quantum criticality identified as the vanishing of the second variation of Kähler action at least for the deformations defining (gauge) symmetries of Kähler action [K17, K5]. Criticality guarantees the conservation of the Noether charges assignable to the Kähler-Dirac action but does not guarantee their non-vanishing. Ideal cosmic strings are excluded because they fail to satisfy the conditions characterizing the preferred extremal as a space-time surface containing regions with both Euclidian and Minkowskian signature of the induced metric with light-like 3-surface separating them identified as orbits of partonic 2-surfaces carrying elementary particle quantum numbers. The topological condensation of CP_2 type vacuum extremals representing fermons generates negative contribution to the action and reduces the string tension and leaves cosmic strings still free.

2. If the topologically condensate of fermions has net Kähler charges as the model for matter antimatter asymmetry suggests, the repulsive interaction of the particles tends to thicken the cosmic string by increasing the thickness of its infinitely thin M^4 projection so that Kähler magnetic flux tubes result. These flux tubes are ideal candidates for the carriers of dark matter with a large value of Planck constant. The criterion for the phase transition increasing $\hbar$ is indeed the presence of a sufficiently dense plasma implying that perturbation theory in terms of $Z^2\alpha_{em}$ (Z is the effective number of charges with interacting with each other without screening effects) fails for the standard value of Planck constant. The phase transition $\hbar_0 \rightarrow \hbar$ reduces the value of $\alpha_{em} = e^2/4\pi\hbar$ so that perturbation theory works. This phase transition scales up also the transversal size of the cosmic string. Similar criterion works also for other charges. The resulting phase is anyonic if the resulting 2-surfaces containing almost spherical portions connected by flux tubes to each other encloses the tip of the causal diamond (CD). The proposal is that dark matter resides on complex anyonic 2-surfaces surrounding the tips of CDs.

3. The topological condensation of cosmic strings generates wormhole contacts represented as pieces of CP_2 type vacuum extremals identified as bosons composed of fermion-anti-fermion pairs. Also this generates negative action and can make cosmic string a preferred extremal of Kähler action. The earliest picture was based on dynamical cancelation mechanism involving generation of strong Kähler electric fields in the condensation whose action compensated for Kähler magnetic action. Also this mechanism might be at work. Cosmic strings could also form bound states by the formation graviton like flux tubes connecting them and having wormhole contacts at their ends so that again action is reduced.

4. One can argue that in long enough length and time scales Kähler action per volume must vanish so that the idealization of cosmology as a vacuum extremal becomes possible and there must be some mechanism compensating the positive action of the free cosmic strings. The general mechanism could be topological condensation of fermions and creation of bosons by topological condensation of cosmic strings to space-time sheets.

In this framework zero energy states correspond to cosmologies leading from big bang to big crunch separated by some time interval T of geometric time. Quantum jumps can gradually increase the value T and TGD inspired theory of consciousness suggests that the increase of T might relate to the shift for the contents of conscious experience towards geometric future. In particular, what is usually regarded as cosmology could have started from zero energy state with a small value of T.

2.2.2 Topological condensation of cosmic strings

In the original vision about topological condensation of cosmic strings I assumed that large voids represented by space-time sheets contain "big" cosmic string in their interior and galactic strings near their boundaries. The recent much simpler view is that there are just galactic strings which carry net fermion numbers (matter antimatter asymmetry). If they have also net em charge they have a repulsive interaction and tend to end up to the boundaries of the large void. Since this slows down the expansive motion of strings, the repulsive interaction energy increases and a phase transition increasing Planck constant and scaling up the size of the void occurs after which cosmic strings are again driven towards the boundary of the resulting larger void.

One cannot assume that the exterior metric of the galactic strings is the one predicted by assuming General Relativity in the exterior region. This would mean that metric decomposes as $g = g_2(X^2) + g_2(Y^2)$. $g(X^2)$ would be flat as also $g_2(Y^2)$ expect at the position of string. The resulting angle defect due to the replacement of plane Y^2 with cone would be large and give rise to lense effect of same magnitude as in the case of GUT cosmic strings. Lense effect has not been observed.

This suggests that General Relativity fails in the length scale of large void as far as the description of topologically condensed cosmic strings is considered. The constant velocity spectrum for distant stars of galaxies and the fact that galaxies are organized along strings suggests that these string generate in a good approximation Newtonian potential. This potential predicts constant velocity spectrum with a correct value velocity.

In the stationary situation one expects that the exterior metric of galactic string corresponds to a small deformation of vacuum extremal of Kähler action which is also extremal of the curvature scalar in the induced metric. This allows a solution ansatz which conforms with Newtonian intuitions and for which metric decomposes as $g = g_1 + g_3$, where g_1 corresponds to axis in the direction of string and g_3 remaining $1 + 2$ directions.

2.2.3 Dark energy is replaced with dark matter in TGD framework

The observed accelerating expansion of the Universe has forced to introduce the notion of cosmological constant in the GRT based cosmology. In TGD framework the situation is different.

1. The gigantic value of gravitational Planck constant implies that dark matter makes TGD Universe a macroscopic quantum system even in cosmological length scales. Astrophysical systems become stationary quantum systems which participate in cosmic expansion only via quantum phase transitions increasing the value of gravitational Planck constant.

2. Critical cosmologies, which are determined apart from a single parameter in TGD Universe, are natural during all quantum phase transitions, in particular the phase transition periods increasing the size of large voids and having interpretation in terms of an increase of gravitational Planck constant. Cosmic expansion is predicted to be accelerating during these periods. The mere criticality requires that besides ordinary matter there is a contribution $\Omega_\Lambda \simeq .74$ to the mass density besides visible matter and dark matter. In fact, also for the over-critical cosmologies expansion is accelerating.

3. In GRT framework the essential characteristic of dark energy is its negative pressure. In TGD framework critical and over-critical cosmologies have automatically effective negative pressure. This is essentially due to the constraint that Lorentz invariant vacuum extremal of Kähler action is in question. The mysterious negative pressure would be thus a signal about the representability of space-time as 4-surface in H and there is no need for any microscopic description in terms of exotic thermodynamics.

2.2.4 The interpretation of accelerated expansion and the values for the TGD counterpart of the cosmological constant

Dark energy characterized by cosmological constant provides a satisfactory description of the accelerated expansion in GRT framework and should have TGD counterpart.

1. If the accelerated expansion is due to the phase transitions changing the value of Planck constant, one can introduce a parameter characterizing the contribution of the dark mass to the mass density during critical periods and call it cosmological constant recalling however that the contribution does not correspond to dark energy in the standard sense. The negative pressure of the almost unique critical cosmology would be a space-time correlate for the phase transition increasing the Planck constant.

2. There is also an alternative interpretation. According to the earlier proposal, string like objects resulting as descendants of primordial cosmic string are carriers of the dark energy. If the string like objects correspond to space-time sheets mediating gravitational interaction and have a gigantic gravitational Planck constant $\hbar_{gr} = GMm/v_0$, with $v_0/c \leq 1$ holds true

as proposed in [K10] ($v_0 = 2^{-11}$ for the 4 inner planets), one can indeed understand why dark energy density is a constant in such an excellent approximation (Compton lengths of particles would be gigantic: Planck mass would correspond to Compton length of order Schwartschild radius for $\hbar_{gr} \sim GM^2/c$). The negative pressure assigned to dark energy would reflect the negative string tension of string like objects.

3. These two views a conform if the negative pressure of the critical cosmology is due to the presence of string like objects. Cosmological constant would be the natural parameter in GRT based description and replaced in TGD framework by the parameter characterizing the duration of the critical cosmology. In the purely classical description based on cosmological constant the accelerated expansion taking place as short jerks would be replaced by a continual accelerated expansion.

What is new that p-adic fractality predicts that Λ scales as $1/L^2(k)$ as a function of the p-adic scale characterizing the space-time sheet implying a series of phase transitions reducing Λ. The order of magnitude for the recent value of the cosmological constant comes out correctly. The gravitational energy density assignable to the cosmological constant is identifiable as that associated with topologically condensed cosmic strings and magnetic flux tubes to which they are gradually transformed during the cosmological evolution.

The naïve expectation would be the density of cosmic strings behaves as $1/a^2$ as function of M^4_+ proper time. The vision about dark matter as a phase characterized by gigantic Planck constant however implies that large voids do not expand in continuous manner during cosmic evolution but in discrete quantum jumps increasing the value of the gravitational Planck constant and thus increasing the size of the large void as a quantum state. Since the set of preferred values of Planck constant is closed under multiplication by powers of 2, p-adic length scales L_p, $p \simeq 2^k$ form a preferred set of sizes scales for the large voids.

Zero energy ontology provides a further view about the situation.

1. In zero energy ontology causal diamonds (CDs) defined as intersections of the future and past directed light-cones are the fundamental building blocks of the world of classical worlds (WCW) identified as a union of sub- WCW s assignable to CDs [K11]. Note that CDs contains CDs within CDs so that fractality results.

2. A particular CD is characterized by its position in M^4, by the value a of the Lorentz invariant distance a between its upper and lower tips, and by the Lorentz boost applied to get the CD from a standard representative. The moduli space for the CD is therefore the union of spaces $M^4 \times L(a)$ where $L(a)$ is Lobatchevski space, and a corresponds to an allowed value of a.

3. The hypothesis that $L(a)$ corresponds to the 3-space of Robertson-Walker cosmology in quantum cosmology with a having interpretation as cosmic time, is highly attractive. p-Adic length scale hypothesis follows if the values of a come as octaves of the CP_2 time scale. In this framework, the classical cosmology associated with CD representing accelerated expansion would serve as a smoothed out space-time correlate for the discrete quantum jump scaling the size of CD by 2.

A further work is required to find whether these different views about accelerated expansion are mutually consistent.

2.2.5 TGD cosmic strings are consistent with the fluctuations of CMB

GUT cosmic strings were excluded by the fluctuation spectrum of the CMB background [E2]. In GRT framework these fluctuations can be classified to adiabatic density perturbations and isocurvature density perturbations. Adiabatic density perturbations correspond to overall scaling of various densities and do not affect the vanishing curvature scalar. For isocurvature density fluctuations the net energy density remains invariant. GUT cosmic strings predict isocurvature density perturbations while inflationary scenario predicts adiabatic density fluctuations.

In TGD framework inflation is replaced with quantum criticality of the phase transition period leading from the cosmic string dominated phase to matter dominated phase. Since curvature scalar vanishes during this period, the density perturbations are indeed adiabatic.

3 More Detailed View About Topological Condensation Of Cosmic Strings

The purpose of this section is to represent in more detail the calculations behind the vision discussed in the previous section. As already noticed, free cosmic strings as such cannot correspond to the absolute minima of the action since their action is large and positive.

3.1 Topological Condensation Of A Positive Energy Cosmic String

It is however useful to build a model of exterior space-time of topologically condensed cosmic string as a solution of Einstein's equations. For a straight string this solution is flat except at the position of the string. What happens is that the 2-dimensional plane orthogonal to the string becomes a conical surface. The angular defect is given by

$$\Delta\phi = \frac{T}{T_{max}} \times 2\pi \ , \ T_{max} = \frac{1}{4G} \ . \tag{3.1}$$

Here the string tension T refers to the gravitational mass density of the string and this is not necessarily identical with the inertial mass density. Obviously $T_{max} = 1/4G$ represents an upper bound for the gravitational mass density of the string.

The metric can be written as

$$\begin{aligned} ds^2 &= dt^2 - dz^2 - \frac{d\rho^2}{k_1^2} - \rho^2 d\phi^2 \ , \\ k_1^2 &= 1 - 4GT \ . \end{aligned} \tag{3.2}$$

The embeddings of this metric as an induced metric are easy to find. The simplest embedding is obtained by considering a map $M^4 \to S^1$, where S^1 is a geodesic circle of CP_2. Denoting by Φ the angle coordinate of S^1, one has

$$\begin{aligned} \Phi &= k\rho \ , \\ 1 + R^2k^2 &= \frac{1}{k_1^2} \ . \end{aligned} \tag{3.3}$$

The geodesic lines associated with this metric are easy to find in Cartesian coordinates. In M^4 coordinates the geodesics are slightly curved, which is nothing but the lense effect [E15]. To see what happens consider geodesic lines in the plane; cut from the plane a sector corresponding to the deficit angle and bend it to form a cone; after this operation project the geodesic lines on the cone to the plane again to see how the geodesics look like in M^4 coordinates. The observation of this bending is possible if the coordinates used by the observers are actually M^4 coordinates rather than space-time coordinates.

The predicted lense effect would serve as a signature for the presence of strings with this kind of exterior metric and the experimental absence of this effect suggests that this metric is not a proper choice for the exterior metric but should be replaced with a metric inspired by Newtonian intuition.

3.2 Exterior Metrics Of Cosmic String As Extremal Of Curvature Scalar

Einstein action with induced metric in general gives also solutions for exterior metric which are not gravitational vacua. One might hope these solutions in the first approximation correspond to Newtonian expectations and give rise only to a small lense effect. One must of course keep in mind that Einstein's equations and their TGD variant hold true only in long length scales and their application in the scale of cosmic string might not be justified. Second point is that it is the inertial energy density of cosmic strings rather than the energy density associated with curvature scalar, which serves as the source term in TGD variant of the Einstein's equations.

3.2.1 The ansatz

A rather general ansatz implying radial induced gauge fields in the background space is given by the following expression in cylindrical coordinates for M^4_+

$$\begin{aligned} m^0 &= \Lambda t \ , \\ cos(\Theta) &= u(\rho) \ , \\ \Phi &= \omega t + k(\rho) + n\phi \ . \end{aligned} \tag{3.4}$$

The reason why this ansatz works is that the components of metric and thus also of curvature tensor depend only on ρ so that field equations reduce to two differential equations. One can get rid of the $g_{t\rho}$ component of the induced metric by assuming $m^0 = \Lambda t + h(\rho)$ as in case of Schwartschild metric.

The interesting components of the induced metric in the cylindrical coordinates are given by the expression

$$\begin{aligned} g_{tt} &= \Lambda^2 - \omega^2 A \ , \\ g_{\rho\rho} &= -1 - A\left[\partial_\rho k)^2 + (\partial_\rho u)^2 \frac{1}{(1-u^2)^2}\right] \ , \\ g_{\rho t} &= -\omega \partial_\rho k A \ , \\ g_{t\phi} &= -\omega n A \ , \\ g_{\rho\phi} &= -\partial_\rho k A \ , \\ A &= R^2\omega^2(1-u^2) \ , \\ \Lambda^2 - \omega^2 A(\infty) &= 1 \ . \end{aligned} \tag{3.5}$$

Note that the induced gauge fields are Abelian. Em and Z^0 fields are proportional to each other and classical color field is proportional to induced Kähler form and vanishes for vacuum extremals. This can be seen as a signature of color confinement.

3.2.2 Field equations as conservation laws

The conservation law for color charge corresponding to $\Phi \rightarrow \Phi + \epsilon$ gives the first differential equation:

$$\partial_\rho \left[(G^{\rho\rho}\partial_\rho k + \frac{G^{\rho\phi} n}{\rho} + G^{\rho t}\omega) sin^2(\Theta)\sqrt{g}\right] = 0 \ . \tag{3.6}$$

For $m^0 + \Lambda t + h(\rho)$ energy conservation one gets rid of the $G^{\rho t}$ term. This equation can be integrated to give

$$(G^{\rho\rho}\partial_\rho k + \frac{G^{\rho\phi} n}{\rho}) sin^2(\Theta)\sqrt{g} = C \ . \tag{3.7}$$

and states that the conserved radial flow of $U(1)$ color charge is non-vanishing. This current must flow along the string. Note that for $k = constant$ gives $C = 0$.

The second equation can be chosen to correspond to the momentum conservation in say x-direction and would give

$$\partial_\rho \left[(G^{\rho\rho} + \frac{G^{\phi\rho}}{\rho})\sqrt{g}\right] - G^{\phi\phi}\rho\sqrt{g} = 0 \ . \tag{3.8}$$

The resulting field equations are extremely non-linear ordinary differential equations for $\Theta(\rho)$ and $\Phi(\rho) = k(\rho)$ having a character of a hydrodynamical conservation law. For $n = 0$ one obtains effectively Einstein equations with purely geometric source terms.

$$
\begin{aligned}
G^{\rho\rho} &= \frac{C}{sin^2(\Theta)\partial_\rho k\sqrt{g}} \ , \\
G^{\phi\phi} &= \partial_\rho \left[\frac{C}{sin^2(\Theta)\partial_\rho k}\right]\frac{1}{\rho\sqrt{g}} \ .
\end{aligned}
\tag{3.9}
$$

3.2.3 Linearization

The linearized expression of the Einstein tensor with respect to the deviation $h_{\alpha\beta}$ of the induced metric from flat metric should give a good approximation to the field equations and allow to decide whether the Newtonian picture holds true. The linearized Ricci tensor is given by

$$
\begin{aligned}
2R_{\alpha\beta} &= D_\gamma D_\beta h^\gamma{}_\alpha + D_\gamma D_\alpha h^\gamma{}_\beta - D_\alpha D_\beta h - D_\gamma D^\gamma h_{\alpha\beta} \ , \\
R &= D_\alpha D_\beta h^{\alpha\beta} - D_\alpha D^\alpha h \ .
\end{aligned}
\tag{3.10}
$$

The covariant derivatives are with respect to the flat M^4 metric.

3.2.4 Are field equations consistent with the Newtonian limit?

One can hope that the field equations are consistent with the Newtonian limit which implies $R_{tt} = g_{tt}R/2$ outside z-axis in the linear approximation. If this is true, the gravitational energy density of the exterior metric would remain vanishing in the linear approximation for the metric so that a minimal modification of the vacuum Einstein equations would be in question. That Newtonian limit makes sense could be due to the fact that Einstein tensor represents the action of a non-linear wave operator on metric. Hence metric should be expressible in terms of its sources and topologically condensed cosmic string defines such a source very naturally.

Newtonian limit corresponds to the approximation

$$
g_{tt} - 1 = 2\Phi_{gr} \ , \quad \nabla^2\Phi_{gr} = -4\pi\rho_{gr} \ .
\tag{3.11}
$$

For string tension $T = dM/dl$, which corresponds to the density of inertial mass, one has $\Phi_{gr} = 2TGlog(\rho/\rho_0)$ as the 2-dimensional variant of Gauss law shows. This corresponds to the simplified ansatz

$$
\begin{aligned}
u &= u(\rho) \ , \ \Phi = \omega t + k(\rho) \ , \\
A - A(\infty) &= 2\Phi_{gr} = 4GT \times log(\frac{\rho}{\rho_0}) \ .
\end{aligned}
\tag{3.12}
$$

This gives

$$
\begin{aligned}
u^2 &= u^2(\infty) - K \times log(\frac{\rho}{\rho_0}) \ , \\
K &= \frac{16GT}{R^2\omega^2} \ .
\end{aligned}
\tag{3.13}
$$

The embedding ceases to exist at certain critical radii corresponding to

$$
\begin{aligned}
\frac{\rho_{max}}{\rho_0} &= exp(\frac{u^2(\infty)}{K}) \ , \\
\frac{\rho_{min}}{\rho_0} &= exp(\frac{u^2(\infty)-1}{K}) \ , \\
\frac{\rho_{max}}{\rho_{min}} &= exp(\frac{1}{K}) \ , K = \frac{4GT}{R^2\omega^2} \ .
\end{aligned}
\tag{3.14}
$$

This ansatz with suitably chosen $k_0(\rho)$ could be taken as the lowest order approximation to the solution and one can expand the solution as $X \equiv u^2 = X_0 + \epsilon X_1 + ...$ $k = k_0(\rho) + \epsilon_1 k_1 + ...$ and solve u_n and k_n by linearizing the field equations around $X = X_0 + ...\epsilon^n X_n$ and $k = k_0 + ...\epsilon^n k_n$ solving (X_{n+1}, k_{n+1}) from the linearized differential equations. One could also proceed by substituting to the right hand side n: th order approximation and linearized Einstein tensor to the left hand side using $n+1$: nt order approximation. Note that the ansatz makes sense also for negative gravitational energy.

The angle defect (or surplus) is given by

$$\Delta\Phi(\rho) = \frac{\sqrt{\rho^2 + R^2 u^2 n^2}}{\int_0^\rho \sqrt{g_{\rho\rho}} d\rho} \times 2\pi \quad . \tag{3.15}$$

For small values of n the effect is expected to be small.

3.3 Geodesic Motion In The Exterior Metric Of Cosmic String

Writing the geodesic equations explicitly one finds that the conservation of energy and angular momentum give the conditions

$$\begin{aligned} \frac{dt}{ds} &= E \ , \\ \rho^2 k^2 \frac{d\phi}{ds} &= L \ . \end{aligned} \tag{3.16}$$

In the radial direction one obtains the equation of motion

$$\frac{d^2u}{ds^2} = \frac{u}{1-u^2} \times (\frac{du}{ds})^2 + \frac{L^2}{\rho_0^2} \frac{1-u^2}{u^3} \quad . \tag{3.17}$$

The cosmic string induces besides ordinary centrifugal acceleration a radial repulsive acceleration

$$g = \frac{u}{1-u^2} \times (\frac{du}{ds})^2 \quad . \tag{3.18}$$

The geodesic lines lead to the boundary of the cylindrical region. A possible interpretation is that this acceleration drives galactic cosmic strings with reduced string tension to the boundary of the large void.

The exterior solution does not represent co-moving matter which conforms with the idea that gravitational space-time sheets correspond to gigantic values of Planck constants implying that even astrophysical objects correspond to stationary quantum states following cosmic expansion only in average sense by quantum jumps leading to a reduction of Planck constant and rapid expansion of the space-time sheet. Classical picture would suggests that these jumps occur when the matter has ended up sufficiently near to the boundary of the large void.

Note that if one completes the space-time sheet by gluing "above" it second cosmic string with positive time orientation and positive gravitational mass the geodesic lines could turn around at the boundary so that the accelerated expansion of the matter would transform to compression.

It is easy to see that simple embeddings of almost everywhere flat metric do not exist so that the density of gravitational energy in the exterior region is unavoidable. The condition $g_{\rho\rho} = 1$ could be satisfied by assuming $m^0 = t + h(\rho)$ and choosing h properly. This generates however also $g_{t\rho}$ component to the induced metric and to compensate it one should have $\Phi = n\phi + \omega t + k(\rho)$ with k chosen properly. This however generates $g_{t\phi} \neq 0$ which cannot be canceled and would mean that the solution is rotating.

One obtains also vacuum extremals representing solutions for which gauge charges and angular momentum are non-vanishing by a very simple deformation $\Phi \rightarrow \Phi + \omega t$ of the proposed ansatz. Interestingly, non-vanishing gauge charges are necessarily accompanied by angular momentum and vice versa.

3.4 Matter Distribution Around Cosmic String

The distribution of stars in the vicinity of cosmic string can be modeled using kinetic model for the evolution of the distribution of stars. Assuming that stars have some average mass M and that the situation is non-relativistic the kinetic equation for the distribution of stars reads

$$\frac{dn}{dt} = \nabla\cdot(D\nabla n + \bar{w}n) \ . \quad (3.19)$$

The second term is the divergence of the current consisting of diffusion term and drift term caused by the Kähler force.

The drift velocity $\bar{w}$ is related to the Kähler force F_K

$$\bar{w} = b\bar{F}_K \ , \quad (3.20)$$

where b is the mobility of the star. Assuming that one can associate a well defined temperature parameter to the star distribution the mobility is related to the diffusion constant D by the Einstein relation $D = bT$. Kähler force is expressible in terms of Kähler gauge potential

$$\bar{F}_K = \nabla Q\Phi \ . \quad (3.21)$$

Here $\Phi = kT_sG\omega ln(\rho/\rho_0)$ is the gauge potential of the Kähler electric field. T_s denotes the string tension:

$$T_s \simeq .52 \ \times 10^{-6}\times\frac{\epsilon}{G} \ .$$

The lower bound for ϵ is about 10^{-7} from the previous considerations. Q is the average Kähler charge of the star: $Q \simeq \epsilon M\sqrt{G}$,

An order of magnitude estimate for diffusion constant is given by $D \simeq \langle v\rangle/n\sigma$, where $\langle v\rangle = \sqrt{(T/M)}$ is the average thermal velocity of star and σ is the collision cross section for collisions with other stars.

The equilibrium distribution corresponds to the cancelation of diffusion and drift currents

$$\frac{dn}{dr} \simeq -\frac{M\sqrt{G}\omega}{T}\partial_r\Phi n \ . \quad (3.22)$$

In isothermal case one obtains for the distribution of stars the following expression

$$\begin{aligned} n(\rho) &= n_0exp(-\frac{M\sqrt{G}\Phi_K\omega}{T}) = n_0(\frac{r}{r_0})^{\alpha} \ , \\ \alpha &= \frac{M\sqrt{G}T_sG\omega}{T} \ , \end{aligned} \quad (3.23)$$

so that a power law behavior results. Unfortunately, concerning the value of the temperature parameter there is nothing interesting to say.

The second alternative is based on the adiabaticity assumption

$$\frac{T}{T_0} = (\frac{n}{n_0})^{1-\gamma} \ , \quad (3.24)$$

where γ denotes adiabatic constant. In this case one obtains

$$\begin{aligned} n(r) &= n_0(Aln(\frac{r}{r_0}))^{\frac{1}{(1-\gamma)}} \ , \\ A &= (1-\gamma)M\sqrt{G}T_s\frac{G}{T_0} \ . \end{aligned} \quad (3.25)$$

for the distribution of stars.

3.5 Quantization Of The Cosmic Recession Velocity

The statistical analysis of the observational data about red shift of quasars [E31] shows that the distribution of emission line red shifts of quasars have a periodicity, which can be explained most nicely by assuming that the recession velocity v calculated from red shift is quantized so that one has, using the standard relation between the recession velocity and distance of the emitting object,

$$v = H_0(r_0 + nR) \ . \tag{3.26}$$

Here H_0 denotes the present value of Hubble constant. The order of magnitude for the parameter R is $R \simeq 10^8$ ly.

There is also a problem of the association between galaxies and quasars. There are indications that galaxies and quasars form correlated pairs but that the red shift of the quasar is much larger than the red shift of the galaxy [E19]. In case that the two systems are actually different physical systems, this implies that the red shift of the quasar member is of non-cosmological origin.

Various explanations for these effects have been proposed. For example, the idea that Universe is multiply connected has been put forward [E31]. According to this explanation the emission lines with different red shifts correspond to images of single object: the light emitted from the object can travel several times "around the world" before being detected and the distance to the observe is thus quantized: $r = r_0 + nL$, where L is the size of the non-simply connected Universe. Observations require that L is of the order of $L \simeq 10^8 - 10^9 \ ly$.

The TGD based explanation for the phenomenon is similar in spirit to this explanation (see **Fig. 1**). The original model for the phenomenon turned out to be inconsistent with the revised view about cosmic strings. The model however allows an obvious modification.

3.5.1 Original model for the quantization of red shifts

The original model was based on the idea is that null geodesic lines around the topologically condensed "big" strings ("big" meant that the parameter $K = \omega^2 R^2$ is not too far from unity) do not leave the 3-space surrounding "big" string in the center of large void of radius of order 10^8 ly and carrying strong Kähler electric field canceling its magnetic action: for the simplest geodesic the projection to the plane orthogonal to the string is just circle. Galaxies tend to be situated near the boundaries of the 3-space surrounding big string and the light emitted from quasar can travel several times around the string before being detected (see **Fig. 1**).

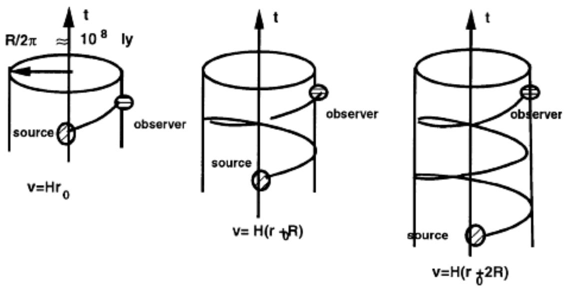

Figure 1: Quantization of the cosmic recession velocity.

A simplified situation is obtained, when the distance R of the emitting quasar and observer from the string is same ($R \simeq 10^8 \ ly$) and when the distance along string direction is L. In this case the projection of the light like geodesic on plane is circle and the motion in z-direction is along straight line. The distance traveled by light before its detection is given by the expression

$$r = \sqrt{L^2 + (r_0 + n2\pi R)^2} \ . \tag{3.27}$$

If observer and source are in same plane one obtains the previous formula for the quantized recession velocity. The size of the parameter R, which is fixed by the hypothesis that big void regions correspond to cosmic strings is indeed in accordance with the observational constraints.

It is not at all obvious that the orbit of photon can indeed be confined inside the outer critical radius ρ_+ associated with the string having $\omega R \sim 1$: the Kähler charge cannot obviously be all that matters since photons do not couple to it. For "big" strings however $\omega R \sim 1$ holds true. This is indeed the case: the physical reason is the extremely strong gravitational field caused by the big string. To see this consider the equations of motion for an orbit with circular projection in the plane orthogonal to the string. Orbit is characterized by energy conservation condition, momentum conservation condition in the direction of string, masslessness condition and the equation of motion in radial direction (essentially Kepler law)

$$\begin{aligned} \frac{dt}{ds} &= E \ , \\ \frac{dz}{ds} &= p \ , \\ E^2 g_{tt} - p^2 - \rho^2\omega_0^2 &= 0 \ , \\ \rho\omega_0^2 &= \frac{\partial_\rho g_{tt} E^2}{2} \ , \end{aligned} \tag{3.28}$$

The last equation forces the photon to a circular orbit if some additional consistency conditions are satisfied and obviously requires Kähler charged string. The expression for the time component of the metric is given by

$$\begin{aligned} g_{tt} &= 1 - R^2\omega^2(1-u^2) \ , \\ u &= cos(\Theta) = kln(\frac{\rho}{\rho_0}) \ , \\ k &= \frac{1}{ln(\frac{\rho_+}{\rho_0})} \ . \end{aligned} \tag{3.29}$$

Here $u = cos\Theta$ denotes the coordinate variable of the geodesic sphere S^2 as a function of the radial coordinate approaching value $u = -1$ at the boundary of the cylindrical region surrounding big string. These conditions boil down to the following condition fixing the value for the radius ρ of the circular orbit

$$cos(\Theta) = \frac{1}{\sqrt{K}}\sqrt{\frac{1-\frac{p^2}{E^2}-K}{1-\frac{Kk^2}{\omega_0^2\rho^2}}} \ . \tag{3.30}$$

This equation has real solutions provided the argument of the square root term is positive. In addition the condition $|cos\Theta| \leq 1$ must hold true.

If the longitudinal momentum of the photon vanishes, one has

$$cos(\Theta) = \frac{1}{\sqrt{K}}\sqrt{\frac{1-K}{1-\frac{Kk^2}{E^2}}} \ . \tag{3.31}$$

In the approximation $\frac{Kk^2}{E^2} \simeq 0$ this gives the bounds $1/2 < K < 1$. This condition is not consistent with the assumption that $K = R^2\omega^2$ is a small parameter given by

$$K = \frac{\epsilon}{2\alpha_K k} \ .$$

The small value of K is consistent with $p/E \simeq 1$ so that most of photons momentum is in the direction of string. The result means that the original model based on "big" strings in the center of the large void and explaining the observations must be given up.

3.5.2 Modified model for the quantization of red shifts

The modification of the previous model is obvious and much analogous to the topological model for the quantization. If closed galactic strings and torus like space-time sheets containing them and winding around the boundary of the large void are closed and are able to confine photons inside them and thus acting as cosmic wave guides, the photons from a distant star can rotate several times along these space-time sheets and same quantization of the red shift would result also now.

If the proposed explanation for the quantized red shift is correct, one can in principle observe the time development of single object from quasar to galaxy by a series of images, the time difference between two successive images being of the order of 10^8 ly. These images are observed on the same line of sight, when the light comes from a distant object.

4 Cosmic Evolution And Cosmic Strings

In this section a general vision about cosmic evolution based on zero energy ontology is discussed.

4.1 Cosmic Strings And Generation Of Structures

p-Adic fractality and simple quantitative observations lead to the hypothesis that cosmic strings are responsible for the evolution of astrophysical structures in a very wide length scale range. Large voids with size of order 10^8 light years can be seen as structures containing near their boundaries long cosmic strings at around which galaxies are organized linear structures like pearls in string. The original model contained big string in the center of void but it might well be possible to do without it. Galaxies would correspond to similar string like structure with smaller size and linked around the supra-galactic strings. This indeed conforms with the finding that galaxies tend to be grouped along linear structures. Simple quantitative estimates show that even stars and planets could be seen as structures formed around cosmic strings of appropriate size. Thus Universe could be seen as fractal cosmic necklace consisting of cosmic strings linked like pearls around longer cosmic strings linked like...

The observed quantization of the cosmic recession velocity [E31] supports the proposed view. The space-time sheet of large void containing galactic cosmic strings is closed structure. The photons from a distance astrophysical experience radial outwards acceleration and are drifted to the boundaries of the void but they cannot escape this space-time sheet. Hence these photons can be detected after having traversed several times around the closed loop and the red shift is proportional to the number of traversals. In case of larger void the order of magnitude for the quantization is predicted correctly.

4.2 Generation Of Ordinary Matter Via TGD Counterpart Of Hawking Radiation?

Cosmic strings can reduce their inertial masses by the analog of Hawking radiation involving the generation of fermion particle-antiparticle pairs, whose negative energy member remains inside string and annihilates there and positive energy member is radiated away. This mechanism can generate ordinary matter during initial stages of cosmic evolution and its temporal mirror image could give rise to a process analogous to the flow of ordinary matter to a black-hole during the final stages of the cosmic evolution. Highly tangled strings indeed within volume whose radius corresponds to black-hole radius indeed define a very general TGD based microscopic model of a black-hole. This "Hawking radiation" could generate at least part of the visible matter. The splitting of cosmic strings followed by a "burning" of the string ends provides a second manner to generate visible matter.

4.3 How Single Cosmic String Could Reduce Its Kähler StringTension?

The string tension of cosmic strings is due to Kähler action and has microscopic interpretation in terms of the mass of wormhole contacts having boson interpretation and fermions and super-symplectic bosons which correspond to topologically condensed CP_2 type vacuum extremals. The model of hadrons suggests that super-symplectic bosons could dominate the mass of cosmic string.

If one accepts the general formula for the string tension in terms of Kähler coupling strength and quantum classical correspondence, one must conclude that the total contribution of matter to string tension equals to that of Kähler action.

One can imagine several mechanisms for how cosmic string could reduce its string tension. The topological condensation of CP_2 type vacuum extremals generates negative Kähler action so that string tension is reduced. The fact that Kähler action for the infinitely thin cosmic strings depends only on Kähler coupling strength suggests that the cosmic string transforms somehow in the process so that Kähler magnetic field flux remains constant but magnetic energy is reduced. This happens if the cosmic string develops finite transversal size in M^4 degrees of freedom since energy for magnetic flux tubes behaves as $1/S$, S the transversal thickness.

TGD predicts what I have used to call super-symplectic bosons and also their super-partners carrying having fermionic quantum numbers of right handed neutrino [K5]. These bosons have no electro-weak interactions and define a particular candidate for dark matter. Super-symplectic boson corresponds to single wormhole throat just like fermions and string like hadronic space-time sheets containing super-symplectic bosons and their super-partners connected by join along boundaries bonds to partonic space-time sheets have a key role in the recent model of hadrons. Also the model of black-hole as a gigantic hadron like entity relies on them. Two kinds of black-holes, "fermionic" and "bosonic" corresponding to strings and pairs of strings suggest themselves.

4.4 Zero Energy Ontology And Cosmic Strings

The combination of zero energy ontology with the cosmic evolution inspires concrete ideas about what the localization of contents of consciousness experience around narrow time interval identified as moment of subjective time could mean.

4.4.1 Zero energy ontology and cosmic evolution

Zero energy ontology means that all matter is creatable from vacuum as zero energy states which can be decomposed to positive and negative energy states whose space-time correlates correspond to partonic 2-surfaces in geometric past and future. This suggests strongly a picture about cosmic evolution beginning with TGD counterpart of Big Bang and ending with that of Big Crunch. It is however more appropriate to speak about "a silent whisper amplified to a big bang" since the amount of gravitational energy of cosmic strings in co-moving volume approaches zero at the limit of initial singularity.

This picture means genuine temporal non-locality and correlations over time interval T characterizing the distance between Bang and Crunch. It is however quite possible that T increases quantum jump by quantum jump and has been very small in past. The gradual shifting of the future end of zero energy state to the geometric future might relate directly to the arrow of subjective time. The usual identification of subjective time with geometric time can be understood if the arrow of subjective time corresponds to the gradual shift of the space-time volume from which the contents of conscious experience are to geometric future. TGD of course predicts a fractal hierarchy of cosmologies within cosmologies. Even elementary particle reactions have interpretation in terms of zero energy states identifiable as kind of mini-cosmologies.

If the main contribution to the contents of consciousness comes from the upper end of the zero energy state, and if T increases quantum jumps by quantum jump, this correlation could be understood and biological life cycle might have interpretation in terms of cosmology in human time scale at some level of dark matter hierarchy. Interestingly, the apparent increase of order suggests that the crunch phase might be experienced as a kind of Ω point. We could live all the subjective time at the Ω point which shifts to the geometric future quantum jump by quantum jump.

In the case of cosmic strings zero energy ontology would mean that cosmic strings are created in pairs of positive and negative energy cosmic strings. The mechanism could be non-local in the sense that the strings need not form tightly correlated pairs. An analogy with TGD based description of particle reaction would allow positive energy fermions from the geometric past and negative energy fermions from geometric future to meet somewhere in between. Bosons would correspond to tightly correlated pairs of positive and negative space-time sheets connected by wormhole contacts.

If the mechanism of generation of strings is local, "bosonic" strings formed by pairs of positive and negative inertial energy cosmic strings connected by connected by wormhole contacts would appear near the bang and crunch so that the density of inertial energy would vanish at this limit. With respect to geometric time single sub-cosmology would correspond to kind of vacuum polarization event for inertial energy. Locality assumption is however not necessary but would be consistent with the fact that Robertson Walker cosmology for which inertial mass density vanishes works so well.

4.4.2 The new view about second law

Quantum classical correspondence suggests negative and positive energy strings (in the sense of zero energy ontology) tend to dissipate backwards in opposite directions of the geometric time in their geometric degrees of freedom. Time reversed dissipation of negative energy states looks from the point of view of systems consisting of positive energy matter self-organization and even self assembly. The matter at the space-time sheet containing strings in turn consists of positive energy matter and negative energy antimatter and also here same competition would prevail.

This tension suggests a general manner to understand the paradoxical aspects of the cosmic and biological evolution.

1. The first paradox is that the initial state of cosmic evolution seems to correspond to a maximally entropic state. Entropy growth would be naturally due to the emergence of matter inside cosmic strings giving them large p-adic entropy proportional to mass squared [K5, K14]. As strings decay to ordinary matter and transform to magnetic flux tubes the entropy related to translation degrees of freedom increases.

2. The dissipative evolution of matter at space-time sheets with positive time orientation would obey second law and evolution of space-time sheets with negative time orientation its geometric time reversal. Second law would hold true in the standard sense as long as one can neglect the interaction with negative energy antimatter and strings.

3. The presence of the cosmic strings with negative energy and time orientation could explain why gravitational interaction leads to a self-assembly of systems in cosmic time scales. The formation of supernovae, black holes and the possible eventual concentration of positive energy matter at the negative energy cosmic strings could reflect the self assembly aspect due to the presence of negative energy strings. An analog of biological self assembly identified as the geometric time reversal for ordinary entropy generating evolution would be in question.

4. In the standard physics framework the emergence of life requires extreme fine tuning of the parameters playing the role of constants of Nature and the initial state of the Universe should be fixed with extreme accuracy in order to predict correctly the emergence of life. In the proposed framework situation is different. The competition between dissipations occurring in reverse time directions means that the analog of homeostasis fundamental for the functioning of living matter is realized at the level of cosmic evolution. The signalling in both directions of geometric time makes the system essentially four-dimensional with feedback loops realized as geometric time loops so that the evolution of the system would be comparable to the carving of a four-dimensional statue rather than approach to chaos.

4.5 A New Cosmological Finding Challenging General Relativity

Rachel Bean has published a cosmological finding which- if correct- challenges General Relativity or at least the cosmology based on cold dark matter. The title of the article [E41] is *A weak lensing detection of a deviation from General Relativity on cosmic scales*. Both Sean Carroll [E9] and Lubos Motl [E10] commented the finding. The article *Cosmological Perturbation Theory in the Synchronous and Conformal Newtonian Gauges* [E37] by C.P. Ma and E. Bertschinger allows to understand the mathematics related to the cosmological perturbation theory necessary for a deeper understanding of the article of Bean.

The message of the article is that under reasonable assumptions General Relativity leads to a wrong prediction for cosmic density perturbations in the scenario involving cold dark matter and cosmological constant to explain accelerated expansion. The following represents my first impressions after reading the article of Rachel Bean and the paper about cosmological perturbation theory.

4.5.1 Assumptions

"Reasonable" means at least following assumptions about the perturbation of the metric and of energy momentum tensor.

1. The perturbations to the Robertson-Walker metric contain only two local scalings parameterized as $d\tau^2 \rightarrow (1+2\Psi)d\tau^2$ and $dx^i dx_i \rightarrow (1-2\Phi)dx^i dx_i$. Vector perturbations and tensor perturbations (gravitational radiation classically) are neglected.

2. The traceless part (in 3-D sense) of the perturbation of energy momentum tensor vanishes. Geometrically this means that the perturbation does not contain a term for which the contribution to 3-curvature would vanish. In hydrodynamical picture the vanishing of this term would mean that the mass current for the perturbation contains only a term representing incompressible flow. During the period when matter and radiation were coupled this assumption makes sense. The non-vanishing of this term would mean the presence of a flow component - say radiation of some kind- which couples only very weakly to the background matter. Neutrinos would represent one particular example of this kind of contribution.

3. The model of cosmology used is so called ΛCDM (cosmological constant and cold dark matter).

These assumptions boil down to a simple equation

$$\eta = \Phi/\Psi = 1. \tag{4.1}$$

4.5.2 The results

The prediction can be tested and Rachel Bean indeed did it.

1. Ψ makes itself visible in the motion of massive objects such as galaxies since they couple to Newton's potential. This motion in turn makes itself visible as detected modifications of the microwave background from ideal. The so called Integrated Sachs-Wolfe effect [E5] is due to the redshift of microwave photons between last surface of scattering and Earth and caused by the gravitational fields of massive objects. Ordinary matter does not contribute to this effect but dark energy does.

2. η makes itself visible in the motion of light. The so called weak lensing effect [E7] distorts the images of the distant objects: apparent size is larger than the real one and there is also distortion of the shape of the object.

From these two data sources Rachel Bean is able to deduce that η differs significantly from the GRT value and concentrates around $\eta = 1/3$ meaning that the scaling of the time component of the metric perturbation is roughly 3 times larger than for spatial scaling.

4.5.3 What could be the interpretation of the discrepancy?

What $\eta = 1/3$ could mean physically and mathematically?

1. From [E37] one learns that for neutrinos causing shear stress one has $\Phi = (1 + 2R_\nu/5)\Psi$, where R_ν is the mass fraction of neutrinos: hence η should increase rather than decrease! If this formula generalizes, a negative mass fraction $R = -5/3$ would be present! Something goes badly wrong if one tries to interpret the result in terms of the perturbations of the density of matter - irrespective of whether it is visible or dark!

2. What about the perturbations of the density of dark energy? Geometrically $\eta = 1/3$ would mean that the trace of the metric tensor defined in terms of the background metric is not affected. This means conservation of the metric determinant for the deformations so that small four-volumes are not affected. As a consequence, the interaction term $T^{\alpha\beta}\delta g_{\alpha\beta}$ receives a contribution from $G^{\alpha\beta}$ but not from the cosmological term $\Lambda g^{\alpha\beta}$. This would suggest that

the perturbation is not that of matter but of the vacuum energy density for which one would have

$$\Lambda g^{\alpha\beta}\delta g_{\alpha\beta} = 0 \ . \tag{4.2}$$

The result would not challenge General Relativity (if one accepts the notion of dark energy) but only the assumption about the character of the density perturbation. Instead of matter it would be the density of dark energy which is perturbed.

4.5.4 TGD point of view

What TGD could say about this.

1. In TGD framework one has many-sheeted space-time, dark matter hierarchy represented by the book like structure of the generalized embedding space, and dark energy is replaced with dark matter at pages of the book with gigantic Planck constant so that the Compton lengths of ordinary particles are gigantic and the density of matter is constant in long scales so that one can speak about cosmological constant in General Relativity framework. The periods with vanishing 3-curvature are replaced by phase transitions changing the value of Planck constant at some space-time sheets and inducing lengthening of quantum scales: the cosmology during this kind of periods is fixed apart from the parameter telling the maximal duration of the period. Also early inflationary period would correspond to his kind of phase transition. Obviously, many new elements are involved so that it is difficult to say anything quantitative.

2. Quantum criticality means the existence of deformations of space-time surface for which the second variation of Kähler action vanishes. The first guess would be that cosmic perturbations correspond to this kind of deformations. In principle this would allow a quantitative modelling in TGD framework. Robertson-Walker metrics correspond to vacuum extremals of Kähler action with infinite spectrum of this kind of deformations (this is expected to hold true quite generally although deformations disappear as one deforms more and more the vacuum extremal).

3. Why the four-volumes defined by the Robertson-Walker metric should remain invariant under these perturbations as $\eta = 1/3$ would suggest? Are the critical perturbations of the energy momentum tensor indeed those for the dominating part of dark matter with gigantic values of Planck constant and having an effective representation in terms of cosmological constant in GRT so that the above mentioned equations implying conservation of four-volume result as a consequence?

4. The most natural interpretation for the space-time sheets mediating gravitation is as magnetic flux tubes connecting gravitationally interacting objects and thus string like objects of astrophysical size. For this kind of objects the effectively 2-dimensional energy momentum tensor is proportional to the induced metric. Could this mean -as I proposed many years ago when I still took seriously the notion of the cosmological constant as something fundamental in TGD framework- that in the GRT description based on the replacement string like objects with energy momentum tensor the resulting energy momentum tensor is proportional to the induced metric? String tension would explain the negative pressure preventing the identification of dark energy in terms of ordinary particles.

5. It is not clear whether the GRT based explanation of the accelerated expansion in terms of cosmological constant describing the presence of cosmic strings with large Planck constant conforms with the explanation in terms of phase transitions increasing Planck constant to which TGD assigns critical cosmology with negative string tension. Can one say that the presence of cosmic strings with gigantic Planck constant induces these phase transitions?

6. Note that the gigantic value of $\hbar_{gr}$ implies that for the energies usually assigned with gravitons the wave-length would be enormous so that these gravitons could correspond to string like

objects connecting source and detector! Dark graviton with a frequency typically assignable to an astrophysical system would have enormous energy. Dark gravitons would decay to bunches of ordinary gravitons before arriving the detector [K16] so that the flux of ordinary gravitons would not be constant.

5 Cosmic String Model For Galaxies And Other Astrophysical Objects

The new view about the relationship between gravitational and inertial energy forces to modify the original model based of galaxy based on split cosmic strings. Splitting, although possible, might not be needed since Hawking radiation might replace it as a basic mechanism generating visible matter. By p-adic fractality the mechanism generalizes and provides a universal mechanism for the generation of astrophysical structures and universe can be seen as fractal necklace containing coiled pairs of cosmic strings linked around larger structures of similar kind linked...

5.1 Cosmic Strings And The Organization Of Galaxies Into Linear Structures

Astronomical observations suggest that galaxies form linear structures [E47]. This inspired the original TGD based model of galaxies as decay products of split cosmic strings forming kind of cosmic fire crackers. The required order of magnitude for the string tension was of order $10^{-6}/G$ the same as the string tension of the cosmic strings predicted by TGD (so that CP_2 radius would reflect itself directly in the galactic dynamics!). The model suggested also a solution of galactic dark matter problem since the net mass of a ball containing string is expected to depend linearly on the radius of the ball as indeed found.

One problem of this model was that galactic strings ought be in the plane of the galaxy. The galactic jets which one might expect to be parallel to the strings are however orthogonal to the galactic plane which suggests that visible matter condensed on certain points of a long string roughly orthogonal to the galactic plane.

The new view about the relationship between inertial and gravitational energy and the necessity of cosmological constant forces to modify this scenario.

1. The observation that galaxies are organized in linear structures can be understood if the basic structures cosmic strings with string tension determined by Kähler action and winding in a spaghetti like manner along the boundaries of large voids. Part of ordinary matter would results as a Hawking radiation from these strings but the very fact these strings are mostly invisible suggests that the matter emitted by them remains in the vicinity of strings. Visible jets orthogonal to the galactic plane usually interpreted in terms of black hole emissions could correspond to the emission of Hawking radiation from these structures. Galaxies are concentrations of visible matter around these strings and they are roughly orthogonal to the plane of galaxy.

2. The generation of positive and negative energy matter with zero net energy from vacuum does not contribute to the inertial energy in time scales longer than the scale of causal diamond (CD) involved. This has occurred already during string dominated critical period during which the density of gravitational mass behaves as $\rho \propto 1/a^2$ as a function of the light cone proper time and the mass per co-moving volume is proportional to a. The fractality of TGD inspired cosmology suggests that the creation pairs of positive and negative energy cosmic strings giving rise to cosmologies inside cosmologies has occurred also later in smaller length scales. In particular, galaxies and even smaller structures could be seen as cosmologies within cosmologies. Pairs of cosmic strings and magnetic flux tubes are not visible and are thus excellent candidates for the dark matter. The non-conservation of inertial and gravitational energy identified locally as energy associated with positive energy part of the local zero energy state supports this view.

   If the initial inertial and gravitational mass per unit length of these objects is same as that for a free string, the order of magnitude for the gravitational energy density of dark matter per volume is predicted correctly if the length L of string inside sphere R is proportional to its radius: $L \propto R$. Galaxies could be strongly knotted relatively short cosmic strings linked around the long cosmic strings like pearls in a necklace. Their shortness would mean that they do not contribute significantly to the mass of the void.

3. p-Adic fractality suggests that even smaller astrophysical structures might involve strings linked with larger strings linked with...., the cosmic necklace would be a fractal necklace. In the case of Sun a string of length $L \sim 10^{11}$ m, which is not far from the distance $AU = 1.5 \times 10^{11}$ m between Earth and Sun, would be needed whereas the radius of Sun is $\sim 7 \times 10^8$ meters. Thus the magnetic flux tubes resulting form these strings could wind around solar system and bind the entire system into single coherent magnetic structure. For Earth one would have $L \sim 3 \times 10^5$ m, which is smaller than the radius $R = 6.4 \times 10^6$ m of Earth. What makes this interesting is that quite recently it has been announced that Earth contains a previously unidentified core region with size of 3×10^5 m [F1]. This picture suggest a universal mechanism for the evolution of the solar system replacing the existing Newtonian model based on the amplification of gravitational perturbations.

5.2 Cosmic Strings And Dark Matter Problem

Consider now the idea that the presence of cosmic strings might solve the dark matter puzzle [E39]. The presence of the dark matter is indicated by the velocity spectrum of the distant stars (at distance of few tens of kilo-parsecs from the center of the galaxy), which according to the recent observations [E25, E32] approaches to a constant depending on the galaxy in question and having the general order of magnitude $V \simeq 10^{-3}$.

One can estimate the velocity V of a distant star in galactic plane from Kepler law (the spherically symmetric model for galaxy suggests that this argument indeed applies)

$$\frac{V^2}{R} = \frac{GM(R)}{R^2} , \quad (5.1)$$

where $M(R)$ denotes the mass inside a sphere of radius R. Since the mass of the cosmic string dominates the mass inside a sphere of radius R one gets the following very rough estimate for the effective gravitational mass inside the sphere of radius R

$$M(R) \simeq n2TR , \quad (5.2)$$

where $n > 1$ accounts for the fact that straight string is not in question. From the known velocity V one obtains for the string tension the estimate

$$T \sim \frac{V^2}{4nG} \sim \frac{10^{-6}}{4nG} \sim v_D T_{free} . \quad (5.3)$$

This estimate is of the same order of magnitude as the lower bound of string tension obtained from the Jeans criterion. The result is also consistent with the assumption that, due to their gravitational binding to strings, stars rotate with the same velocity as strings.

Recall that an upper bound for the string tension of the TGD cosmic string is given by

$$T = \frac{1}{8\alpha_K R^2} \simeq .52 \times 10^{-6} \frac{1}{\hbar_0 G} .$$

This is roughly twice the required tension for $n = 1$ so that TGD is consistent with the experimental input. The effective string tension of the co-moving string also increases for $r \to r_0$ (see the general description of cosmic string solution) and diverges at $r = 0$. Furthermore, since the cosmic string is not straight there appears additional factor n making $M(R)$ larger than the simple estimate above.

On basis of these observations one has a strong temptation to think that the still existing cosmic strings, possibly thickened to magnetic flux tubes, correspond to galactic and extragalactic dark matter. At this stage one must leave open whether the naïve argument leads to a correct form for the velocity spectrum of stars. Whether or not true this prediction would have nice features in that it would relate the velocity spectrum directly to the size and age of the galaxy since the velocity v determines the recent size of the visible galaxy (if it corresponds to the recent distance of the string end from the center of galaxy): the older the galaxy with given size the smaller the rotational velocity v. Elliptic galaxies are older than spiral galaxies: rotational velocities for the elliptic galaxies are indeed smaller than for spiral galaxies [E32]. Furthermore, the rotational velocities increase with the size of the galaxy, when the age of the galaxy is kept constant: also this feature is in qualitative accordance with observed facts [E25, E32].

An interesting question is whether one could explain the angular momentum of galaxies in terms of the tidal forces acting between the galaxies [E18] at the opposite ends of a string (having length of order 10^5 light years. The idea is following. For free cosmic string there is a flux of angular momentum of order Tar^2 (using Robertson-Walker coordinates (a, r))) through the end of the string, which produces a correct order of magnitude for the galactic angular momentum at time a given by $J \sim Ta^2r^2 = Tr_M^2$, $r_M \sim 10^5\ ly$.

5.3 Estimate For The Velocity Parameters

The first task is to fix the value of the velocity parameter, to be denoted by V, appearing in the general solution describing one arm of the split cosmic string. In the region, where linearized equations of motion hold the orbital velocity V of the cosmic string is constant.

The radius of the singular region associated with cosmic string increases with some velocity v_D identifiable as the velocity with which the size of a typical galaxy (defined for example as the distance of spiral arm L from the center of galaxy) is about $L \simeq 10^4 - 10^5$ light years [E38, E30]. The condition $vT < L$, where $T \simeq 10^9 - 10^{10}$ years is the typical age of the galaxy, gives the estimate

$$v_D \quad < \quad 10^{-5} \ , \tag{5.4}$$

for the velocity v_D using the velocity of light as unit.

One can relate the velocity v_D to the string tension if one accepts the assumption that the relative motion of the string ends results from the shortening of strings, which in turn results from the decay of the string ends to elementary particles (some of them possibly exotics). A rough estimate for the velocity of the shortening of the string [E15] is based on the observation that the velocity

$$v \quad \simeq \quad TG \sim 10^{-6} \tag{5.5}$$

seems to set the time scale for the various dynamical processes leading to the decay of strings [E15]: for example, the shortening of loop with radius L via gravitational radiation as well as the shortening of the string connecting the monopole pair takes place with this velocity [E15]. This velocity is considerably smaller than the typical velocity $V \simeq 10^{-3}$ [E25, E32] of the distant stars moving in the galactic plane, which in turn can be understood using Kepler law.

The idea that the spiral arms of the spiral galaxy correspond to cosmic strings seems to be in accordance with the observational facts. In case of Milky Way [E38] the distance of spiral arms is about $L = 10^4 - 10^5$ light years from the center of the galaxy so that the order of magnitude for the velocity v_D is $v_D \sim 10^{-6} - 10^{-5}$. Furthermore, spiral arms are known to recede from the center of the Milky Way [E38].

The model suggests also an explanation for the observed bar like structure connecting the ends of the spiral arms of the spiral galaxies. The gravitational field is most intense near the string end so that the density of the ordinary matter is expected to be largest near the end of the string. On the other hand, the orbit of the string end is straight line so that "bar" like structure might be formed [E30], when the ends of the spiral arms recede from each other.

It should be stressed that the visible form of galaxies is not so closely related with the form of strings contrary to the original expectations (we used the term "spiral string"). This is clear from the observation that the total change of angle ϕ is smaller than $\pi/2$, which means that simplest cosmic strings are really not "spiral" like. Of course, this result holds for free strings and it might be that condensation in fact creates spiral structure somehow. A more conventional explanation is the generation of density waves with spiral structure [E45] and the presence of strings might have something to do with this phenomenon.

5.4 Galaxies As Split Cosmic Strings?

It is not clear whether the Hawking radiation from a coiled pair of cosmic strings is able to explain galactic visible matter. The reason is that the cosmic strings responsible for linear structures formed by galaxies are not visible along their entire length. One might argue that same applies also the knotted and linked galactic cosmic string pairs. If this is the case, the dark matter problem becomes visible matter problem. A possible solution of the problem is based on split cosmic strings with splitting possibly resulting in the collision of galactic strings with the long supra-galactic strings.

This scenario has indeed some attractive features (see **Fig. ??**).

1. The ends of the split cosmic string create strong gravitational fields and serve as seeds for the galaxy formation. Lense effect [E15] is predicted to be a signature of the string pairs. The fact that spiral galaxies have in general two arms, has a nice topological explanation.

2. One ends up to a rather simple scenario for the evolution of the galaxy.

   (a) The splitting occurs most probably during the string dominated phase for $t < L \sim 10^4\sqrt{G}$ (L is essentially CP_2 radius) and results most naturally from the collision of two strings.

   (b) The split strings begin to decay by emitting particles from their ends. The decay leads to a shortening of the split strings with constant velocity v so that the ends of the split strings recede from each other. This velocity can be identified with the velocity parameter $v \sim TG$ associated with the motion of the spiral arms. A correct size for the visible part of the galaxy is predicted.

   (c) Decaying cosmic string ends provide a model for the "central engines" associated with the galactic nuclei [E34]. The energy production by string decay turns out to be of same order of magnitude as the energy production in quasars assuming that the energy is produced in a narrow jet parallel to the string (momentum conservation favors this option). This was proposed as an explanation for the visible jets associated with the active galaxies as resulting from the interaction of the decay products with the ordinary matter. The fact that these jets are orthogonal to the galactic plane suggests Hawking radiation from supra-galactic string stimulated by the collision as an alternative explanation.

   (d) Co-moving cosmic strings happen to rotate with the same velocity as distant stars (relative to the center of galaxy) are found to rotate. The gravitational binding of stars by the average gravitational field created by cosmic strings would explain the rotational velocity spectrum.

In the following the model will be discussed in more detail to see whether it really works. The value for the velocity parameter v will be derived, Jeans criterion for the formation of the structures around a split cosmic string will be discussed, a simple toy model for a galaxy using spherically symmetric mass distribution will be constructed and the possibility that cosmic strings might provide a solution to the galactic dark matter problem will be studied.

5.4.1 Jeans criterion for the galaxy formation

It is not obvious that Jeans criterion for the generation of structures by gravitational interaction can be applied to galaxy formation in the recent situation differing so dramatically from Newtonian framework. One can however check what Jeans criterion would give in the case of split cosmic strings [E15].

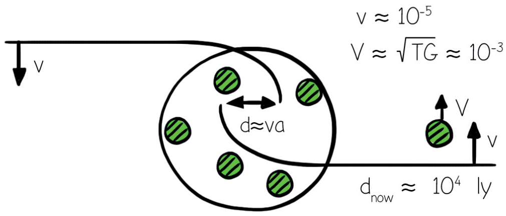

Figure 2: String model for galaxies.

1. The size L of the density fluctuation leading to the formation of a structure satisfies the inequality

$$l_J \quad < \quad L < l_H \ , \tag{5.6}$$

where the Jeans length l_J is given by [E15]

$$l_J \quad \simeq \quad 10 v_s t \ , \tag{5.7}$$

where v_s denotes the velocity of sound. Notice that the formation of structures is not possible at the radiation dominated era since Jeans length is larger than horizon: $l_H \simeq t < l_J \simeq 10t$ since the velocity of sound is of order 1.

2. When radiation and matter decouple from each other (corresponding to the value of about $a_{dec} = 10^8$ light years [E43]), the formation of galaxies becomes possible due to the lowering of the pressure, which leads also to the lowering of the sound velocity v_s from $v_s \simeq 1$ to $v_s \simeq 10^{-5}$ (thermal velocity of hydrogen). Jeans length shortens by a factor 10^{-5} and the formation of structures becomes possible.

In accordance with the idea that the split strings act as seeds for the galaxy formation, one can identify Jeans length as the minimal distance between the ends of the split string, which leads to a formation of galaxy

$$v_D a_{dec} \quad > \quad l_J \ . \tag{5.8}$$

Using the values for a_{dec} and l_J one obtains lower bounds for the velocity v_D between the ends of the galactic string and for the string tension of the galactic strings (accepting the proposed relationship between v_D and string tension)

$$\begin{aligned} v_D &> 10^{-6} \ , \\ T &> \frac{10^{-6}}{G} \ . \end{aligned} \tag{5.9}$$

One obtains also a lower bound for the recent size L_{now} of the galactic nuclei assuming that the decay of galactic strings continues with velocity v_D

$$L_{now} \quad > \quad 10^4 \ ly \ . \tag{5.10}$$

These numbers are in accordance with the estimate obtained for the string tension of a typical galactic strings and with what is known about recent sizes of the galaxies [E30].

5.4.2 Spherically symmetric model

The imbeddability requirement plays central role in TGD inspired cosmology and the galaxy model based on spherically symmetric mass ($M(r) = kr$) distribution is of some interest. This model could be regarded as a large length scale idealization of galaxy mass distribution. In case that galactic dark matter consists of the exotic decay products of the cosmic string the model might be even reasonably realistic. The line element for an energy momentum tensor characterized by energy density $\rho(r)$ and pressure $p(r)$ is given by the expression $ds^2 = A(r)dt^2 - B(r)dr^2 - r^2d\Omega^2$ and to find an embedding for this metric one can use the general embedding ansatz introduced, when discussing the embedding of Reissner- Nordström metric.

Under rather general assumptions about the mass density the time component of the metric for a spherically symmetric mass distribution $M(r)$ (the mass inside the sphere of radius r) is given by the expression $g_{tt} = 1 - 2GM(r)/r$. In present case one would obtain $g_{tt} = constant$ so that some of the underlying assumptions must fail. The following form leads to a correct gravitational force

$$g_{tt} = 1 + 2Gkln(\frac{r}{r_0}) \ . \quad (5.11)$$

The gravitational force in the Newtonian limit is $2Gk/r = 2GM(r)/r^2$ and implies that Kepler law to be used later to derive velocity distribution of distant stars is indeed applicable.

The general expression for the metric component g_{tt} in terms of the embedding ($m^0 = \lambda t, \Theta = \Theta(r), \Phi = \omega t + f(r)$)

$$g_{tt} = \lambda^2 - R^2\omega^2 sin^2(\Theta) \ , \quad (5.12)$$

which gives

$$sin^2(\Theta) = \lambda^2 - 1 - \frac{2Gk}{R^2\omega^2} ln(\frac{r}{r_0}) \ . \quad (5.13)$$

Embedding fails for two critical radii r_{in} ($sin^2|(\Theta) = 1$) and r_{out} ($sin^2(\Theta) = 0$)

$$\begin{aligned} ln(\frac{r_{in}}{r_0}) &= \frac{(\lambda^2 - 1 - R^2\omega^2)}{2Gk} \ , \\ ln(\frac{r_{out}}{r_0}) &= \frac{(\lambda^2 - 1)}{2Gk} \ . \end{aligned} \quad (5.14)$$

An interesting question is whether one could relate the inner critical radii to the existence of the galactic nucleus having diameter of the order of 2 parsecs (.65 light years).

5.5 Cylindrically Symmetric Model For The Galactic Dark Matter

TGD allows also a model of the dark matter based on cylindrical symmetry. In this case the dark matter would correspond to the mass of a cosmic string orthogonal to the galactic plane and traversing through the galactic nucleus. The string tension would the one predicted by TGD. In the directions orthogonal to the plane of galaxy the motion would be free motion so that the orbits would be helical, and this should make it possible to test the model. In this kind of situation general theory of relativity would predict only an angle deficit giving rise to a lens effect. TGD predicts a Newtonian $1/\rho$ potential in a good approximation.

Spiral galaxies are accompanied by jets orthogonal to the galactic plane and a good guess is that they are associated with the cosmic strings. The two models need not exclude each other. The vision about astrophysical structures as pearls of a fractal necklace would suggest that the visible matter has resulted in the decay of cosmic strings originally linked around the cosmic string going through the galactic plane and creating $M(R) \propto R$ for the density of the visible matter in the galactic bulge. The finding that galaxies are organized along linear structures [E47] fits nicely with this picture.

5.6 New Information About The Distribution Of Galactic Dark Matter

The newest discovery relating to the galactic dark matter is described in the popular article “Milky Way Has a ”Squashed Beachball” -Shaped Dark Matter Halo” [E40]. In more formal terms the title states that the orbit of the dwarf galaxy Sagittarius around Milky Way can be understood if the cold dark matter halo is not spherical but ellipsoid with different half axes in each three orthogonal directions. The dark matter distribution allowing the best fit is nearly orthogonal to the galactic plane and looks like a flattened sphere with height equal to one half of the diameter (see the illustration of the article [E40]).

The result is surprising since the most natural expectation is a complete spherical symmetry or ellipsoid with a rotational symmetry around the axes orthogonal to the galactic plane. The complete breaking of the rotational symmetry raises the question whether something might be wrong with the usual dark matter models. The following text is strongly updated version of the original one, which contained several errors and was badly organized.

5.6.1 Observations

Consider first in some detail what has been observed. Since the life span of the astronomers is not astronomical, they are not able to measure the orbit of the dwarf galaxy directly. The orbit of the dwarf galaxy can be however deduced from the stream of stars which Milky Way has ripped out from the dwarf galaxy.

Sagittarius is one of the 14 dwarf galaxies forming a gravitational bound state with Milky Way. It is an elliptic dwarf with a diameter of 10^4 light years (about size as the core of Milky Way). It has rotated about 1 My around Milky Way and already made about 10 full rotations. Now (in astronomical sense) Sagittarius is about to traverse the plane of Milky Way. During its motion Sagittarius experiences enormous tidal forces ripping out stars from it. The resulting stream of ripped out stars marks the orbit of Sagittarius. Obviously Sagittarius loses its mass to Milky Way and has already lost a considerable fraction. The ability of Sagittarius to maintain its coherence has been explained in terms of unusually high dark matter content.

The article states that the study of the paths for the parts of Sagittarius gives different parameters for the dark matter distribution. Maybe the “parts” refer to the four globular clusters of stars belonging to Sagittarius. In any case, a highly refined study of the structure of the star stream left behind by Sagittarius is carried out and one goal has been to find a gravitational potential allowing to fit the paths of the parts deduced from the star debris left behind by Sagittarius. The fact that Sagittarius has made several rotations around Milky Way explains why the “leading star debris” is present in the illustration of [E40]. The movie about the orbit of Sagittarius [E6] gives an artistic simulation about the situation. It seems that an illustration of the actual track from different angles in the galactic plane must be in question.

The basic observation is that the track is in a good approximation in plane. What one can conclude from this depends on what happens in the ripping out process. The star becomes part of Milky Way in some sense. The ripped out star experiences a free fall in the gravitational field of the Milky way. The question concerns what happens to the velocity of the star as it is ripped out.

1. The most natural guess is that the initial velocity is in a good approximation parallel to the velocity at the moment of ripping out.

2. A much stronger assumption is that the star eventually rotates with the same velocity as the distant stars of Milky Way around its center after the ripping out. If the dark matter is also rotating as it should be and forms a halo the gravitational interactions with it could force the hydrodynamic behavior. If one believe that dark matter in astrophysical length scales can have gigantic value of Planck constant, then hydrodynamics behavior looks natural.

5.6.2 Two models of dark matter

TGD allows to consider two alternative models for the dark matter. Contrary to the first guess both models are consistent if the ripping out process is interpreted in the first manner and need not therefore be hydrodynamic. Both models are consistent with the assumption that dark matter corresponds to particles at magnetic flux tubes, which are dark in the sense that they reside at different pages of the book like structure defined by the generalized embedding space with pages labeled by differed values of Planck constant. Magnetic flux tubes can be regarded as outcomes of cosmic expansion thickening the extremely thing cosmic strings and weakening the extremely strong magnetic fields inside them.

Classically dark matter corresponds to the magnetic energy of cosmic string. This interpretation is not locally consistent with the General Relativistic form of the Equivalence Principle if one considers a model for the string like object itself. Einstein's equations however make sense when one considers only the long range gravitational fields created by cosmic strings.

The two models are following.

1. The first model is very similar to the standard models of dark matter. If the galactic dark matter consists of decay products of a closed non-circular cosmic string approximately vertical to the galactic plane, a non-spherically symmetric distribution of dark matter is expected and there is qualitative consistency with the observed squeezed sphere character. If the ripping out leads rapidly to a hydrodynamic behavior the stream of the particles should rotate around Milky Way destroy the planarity of the debris stream. This would be like rocket in straight path through a rotating liquid: the used fuel would start to rotate with fluid.

2. In the second model galactic dark matter as matter resides at long cosmic string perpendicular to galactic plane. The matter in galactic plane could be also partially dark and visible matter could have resulted as decay products of the cosmic string transformed to magnetic flux tube. Galactic strings would have been linked around the long strings like pearls in necklace and this would explain the observed long strings of galaxies.

Consider next in detail the latter model. The very heavy cosmic string like object along the axis perpendicular to the galactic plane creates (in the Newtonian approximation) 2-D logarithmic potential forcing everything to rotate with a constant velocity around it. Besides this there is a weaker nearly vertical acceleration orthogonal to the plane created by the matter in the galactic plane. If the density of the matter in the galactic plane is approximated with a constant density, the motion of the individual star is a superposition of a free fall in the perpendicular direction and scattering in a logarithmic potential of form $Klog(\rho/\rho_0)$ in the approximation that the individual stars of the dwarf galaxy move completely independently. Second extreme would be a hydrodynamic flow.

Sagittarius rotates around the axis orthogonal to the plane of galaxy with the same velocity as the galactic matter identified as the velocity of the distant stars in the galactic plane (the constancy of this velocity led to the discovery of dark matter). Stating it differently, the motion of the stars of dwarf galaxy takes place in a a potential, which is sum of a potential $V_1(\rho)$ depending on the radial coordinate of the plane and a potential $V_2(z)$ depending on the vertical coordinate and created by the galactic matter.

The models differ from each other in several respects.

1. In the first model the simplest gravitational potential would be some function $V(r)$ of the 3-D radial coordinate and in the first approximation logarithmic. The rotation around the axes of Milky way takes place with a smaller velocity as in case of Milky Way and dark matter. The ripping out process is not consistent with the hydrodynamic behavior. The necessity to modify the spherically symmetric distribution of matter might reflect the fact the behavior is actually hydrodynamic.

2. In the second model galactic matter and Sagittarius itself would rotate with approximately the same velocity around the cosmic string and the ripping out process could be rather smooth since the velocity component in the galactic plane would not be affected in the ideal case. This model is consistent with the hydrodynamic behavior. In the optimal situation only the vertical gravitational forces due to the matter in the galactic plane would tend to rip out stars. This might relate to the fact that Sagittarius has been able to maintain its coherence so long. The article "Missing matter mystery of small galaxies" in New Scientist tells about mysterious missing dark matter [E42]. Roughly half of the dark matter predicted by theories is missing. The dark matter at the long cosmic strings would be the natural candidate for this missing dark matter if visible and dark matter in the plane of galaxy identifiable as decay

products of galactic cosmic strings is responsible for the visible matter and already identified dark matter.

5.6.3 Some details related to the central string model

It is interesting to look in more detail the toy model based on cosmic string vertical to the galactic plane (also in this case matter in galactic plane could be decay remnants of a cosmic string). The energies for vertical and transverse motions are conserved separately as is also angular momentum component in vertical direction and one can solve the Newton's equations exactly. By Equivalence Principle one can speak about energy and angular momentum per unit mass: therefore notations e_z, e_T, l for the energies and angular momentum are natural.

1. Energy conservation in the vertical direction gives

$$v_z^2 + 2g_G \times z = 2e_z \quad , \tag{5.15}$$

where g_G is the analog of gravitational acceleration at the Earth's surface and created by a constant density of the galactic matter in the galactic plane.

2. Angular momentum conservation gives

$$\rho^2\omega = l \quad . \tag{5.16}$$

3. The conservation of energy in plane orthogonal to z-axis gives the third conservation law

$$(\frac{d\rho}{dt})^2 + \frac{l^2}{\rho^2} + 2Klog(\frac{\rho}{\rho_0}) = 2e_T \quad . \tag{5.17}$$

These conditions allow to solve the equations of motions for e_z, e_T, and l for each star involved and the mass of the star does not matter at all. In hydrodynamical model correlations between velocities of stars are forced by idealization as continuous matter. In this case the flow lines correspond to classical orbits with gradient of pressure added as an additional force to gravitational force. Energy and angular momentum are conserved along flow lines also now. Situation becomes more complex (and realistic) when one takes into account the gravitational forces between stars.

5.7 Cold Dark Matter In Difficulties

Cold dark matter scenario (see `http://tinyurl.com/lt6ul`) [E1] assumes that dark matter consists of exotic particles having extremely weak interactions with ordinary matter and which clump together gravitationally. These concentrations of dark matter would grow and attract ordinary matter forming eventually the galaxies.

Cold dark matter scenario (CDM) has several problems.

1. Computer simulations support the view that dark matter should be densely packed in galactic nuclei. This prediction is problematic since the constant velocity spectrum of distant stars rotting around galactic nucleus requires that the mass of dark matter within sphere of radius R is proportional to R so that the density of dark matter would decrease as $1/r^2$. This if one assumes that the distribution of dark matter is spherically symmetric.

2. Observations show that in the inner parts of galactic disk velocity spectrum depend linearly on the radial distance (see `http://tinyurl.com/yc4wzcgp`) [E46]. Dark matter density should be constant in good approximation (assuming spherical symmetry) whereas the cold dark matter model represent is strong peaking of the mass density in the galactic center. This is known as core/cusp problem.

3. CDM predicts also large number of dwarf galaxies with mass which would be about one thousandth of that for the Milky Way. They are not observed. This is known as missing satellites problem.

4. CDM predicts significant amounts of low angular momentum material which is not observed.

Already these problems suggest that CDM is somehow wrong. Quite recently a further problem related to dward galaxies has been identified as one learns from Science Daily article Dark Matter Mystery Deepens (see `http://tinyurl.com/np5pmt8`) [E3]. Dwarf galaxies are believed to contain 99 per cent of dark matter and are therefore ideal for the attempts to understand dark matter. They differ from ordinary ones in that stars inside them move like bees in beehive instead of moving along nice circular orbits. The observational data about the structure of dark matter in dwarf galaxies is in conflict with the predictions of cold dark matter scenario. New measurements about two dwarf galaxies tell that dark matter distribution is uniform over a region with diameter of several hundred light years which corresponds to the size scale of the galactic nucleus. For comparison purposes note that Milky Way has at its center a bar like structure with size between 3, 300-16, 000 ly. Notice also that also in ordinary galaxies empirical data support strongly constant density core (core/cusp problem) so that in the real world dwarf galaxies and ordinary galaxies need not be so different after all.

In TGD framework the simplest model for the galactic dark matter assumes that galaxies are like pearls in a necklace. Necklace would be long magnetic flux tube carrying dark energy identified as magnetic energy and galaxies would be bubbles inside the flux tube which would have thickened locally. Similar model would apply to start. The basic prediction is that the motion of stars along flux tube is free apart from the gravitational attraction caused by the visible matter. Constant velocity spectrum for distant stars follows from the logarithmic gravitational potential of the magnetic flux tube and cylindrical symmetry would be absolutely essential and distinguish the model from the cold dark matter scenario.

What can one say about the dwarf galaxies in TGD framework? The thickness of the flux tube is a good guess for the size scale in which dark matter distribution is approximately constant: this is true for any galaxy (recall that dark and ordinary matter would have formed as dark energy transforms to matter). The scale of hundred light years is roughly by a factor of 1/10 smaller than the size of the center of the Milky Way nucleus. If dark matter density equals to the density of dark energy (magnetic energy) which has given rise to the dark matter, dark matter distribution is naturally spherically symmetric and constant in this scale. This could be true also for ordinary galaxies. If so, the cusp/core problem would disappear and ordinary galaxies and dwarf galaxies would not differ in an essential manner as far as dark matter is considered. The problem would be essentially that of cold dark matter scenario.

5.8 Three Blows Against Standard View About Dark Matter

The standard view about dark matter is in grave difficulties.

1. The assumption is that galactic dark matter forms a spherical halo around the galaxy: with a suitable distribution this would explain constant velocity distribution of distant stars. Sometime ago NASA (see `http://tinyurl.com/7ypn8vr`) [E11] reported that Fermi telescope does not find support for dark matter in this sense in small faint galaxies that orbit our own.

2. Another blow (see `http://tinyurl.com/o7rjb2fr`) [E13] against standard view came now. A team using the MPG/ESO 2.2-metre telescope at the European Southern Observatory's La Silla Observatory, along with other telescopes, has mapped the motions of more than 400 stars up to 13, 000 light-years from the Sun. Also in this case the signature would have been the gravitational effects of dark matter. No evidence for dark matter has been found in this volume. The results will be published in an article entitled "Kinematical and chemical vertical structure of the Galactic thick disk II. A lack of dark matter in the solar neighborhood" by Moni-Bidin *et al.* to appear in The Astrophysical Journal.

These findings support the TGD based model for galactic dark matter (to be carefully distinguished from dark matter as large $\hbar$ phases appearing in much smaller amounts and essential for life in TGD inspired quantum biology). TGD based model for the galactic dark matter postulates that the dominating contribution is along long magnetic flux tubes resulting from these during cosmic expansion and containing galaxies around them like pearls in a necklace.

The distribution of dark matter would be concentrated around this string rather than forming a spherical halo around galaxy. This would give rise to a gravitational acceleration behaving like $1/\rho$, where ρ is transversal distance from the string, explaining constant velocity spectrum for distant stars. The killer prediction is that galaxies could move along the string direction freely. Large scale motions difficult to understand in standard cosmology has been indeed observed. It has been also known for a long time that galaxies tend to concentrate on linear structures.

The third blow (see `http://tinyurl.com/lk53s3v`) [E12] against the theory comes from the observation that Milky Way has a distribution of satellite galaxies and star clusters, which rotate around the Milky Way in plane orthogonal to Milky Way's plane. One can visualize the situation in terms of two orthogonal planes such that the second plane contains Milky Way and second one the satellite galaxies and globular clusters. The Milky Way itself has size scale of .1 million light years whereas the newly discovered structure extends from about 33, 000 light years to 1 million light years. The study is carried out by astronomers in Bonn University and will be published in journal Monthly Notices of the Royal Astronomical Society. The lead author is Ph. D. student Marcel Pawlowski.

According to the authors, it is not possible to understand the structure in terms of the standard model for dark matter. This model assumes that galactic dark matter forms a spherical halo around galaxy. The problem is the planarity of the newly discovered matter distribution. Not only satellite galaxies and star clusters but also the long streams of material left - stars and also gas - behind them as they orbit around Milky Way move in this plane. Planarity seems to be a basic aspect of the internal dynamics of the system. As a matter fact, quantum view (see `http://tinyurl.com/mha72yk`) about formation of also galaxies predicts planarity and this allows also to understand approximate planarity of solar system [K9]: common quantization axis of angular momentum defined by the direction of string like object in the recent case with a gigantic value of gravitational Planck constant defining the unit of angular momentum would provide a natural explanation for planarity.

The proposal of the researchers is that the situation is an outcome of a collision of two galaxies.

1. An amusing co-incidence is that the original TGD inspired model (see `http://tinyurl.com/y8wbeo4q`) for the formation of spiral galaxies [K2] assumed that they result when two primordial cosmic strings intersect each other. This would be nothing but the counterpart of closed string vertex giving also rise to reconnection of magnetic flux tubes. Later I gave up this assumption and introduced the model in which galaxies are like pearls in necklace defined by primordial cosmic strings which since then have thickened to magnetic flux tubes. These pearls could themselves correspond to closed string like objects or their decay products. Magnetic energy would transform to matter and would be the analog for the decay of inflaton field energy to particles in inflationary scenarios.

2. As already noticed, in TGD Universe galactic dark matter would correspond to the matter assignable to the magnetic flux tube defining the necklace creating $1/\rho$ gravitational accelerating explaining constant velocity spectrum of distant stars in galactic plane.

Could one interpret the findings by assuming two big cosmic strings which have collided and decayed after that to matter? Or should one assume that the galaxies existed before the collision?

1. The collision would have induced the decay of portions of these cosmic strings to ordinary and dark matter with large value of Planck constant. The magnetic energy of the cosmic strings identifiable as dark energy would have produced the matter. It is however not clear why the decay products would have remained in the planes orthogonal to the colliding orthogonal flux tubes. According to the researchers the planar structures must have existed before the collision.

2. This suggests that the two flux tubes pass near each other and the galaxies have moved along the flux tubes and collided and remained stuck to each other by gravitational attraction. The probability of this kind of galactic collisions depends on what one assumes about the

distribution of string like objects. Due to their mutual gravitational attraction the flux tubes could be attracted towards each other to form web like structures forming a network of cosmic highways. Milky Way would represent on particular node at which two highways form a cross-road. In this kind of situation the collisions resulting s cross-road crashes could be more frequent than those resulting from encounters of randomly moving strings. The galaxies arriving to this kind of nodes would tend to form a bound state and remain in the node. It could also happen that the second galaxy continues its journey but leaves matter behind in the form of satellite galaxies and globular clusters.

It is encouraging that the TGD based explanation for galactic dark matter survives all these three discoveries meaning grave difficulties for the halo model.

6 Cosmic Strings And Energy Production In Quasars

One of the basic mysteries of astrophysics are so called "central engines" in the centers of the galaxies [E34]. These engines are very massive, have very small size of at most few light hours, their luminosity fluctuates in hour time scale, their electromagnetic spectrum is non-thermal and they are often accompanied by two jets in opposite directions. One should also understand why some galaxies are active (have a pair of jets) and others are not. A mysterious property of jets is their microstructure: main jets with length of order 10^6 light years are accompanied by short jets with length of order one light year and with directions parallel to the long jets.

In the standard model the central engine is a galactic black hole but the mechanism of the jet production is not well understood. In the following it is shown that decaying cosmic string ends provide a good candidate for the central engine. Note that in the standard picture jets are orthogonal to galactic plane whereas in the proposed model jets are parallel to the galactic plane. One could consider also the possibility that galaxies are formed in the splitting of cosmic strings orthogonal to galactic plane but this option will not be discussed here.

6.1 Basic Properties Of The Decaying Cosmic Strings

The rate for the shortening of a split galactic cosmic string can be deduced by an order of magnitude argument

$$\begin{aligned} v &\sim kTG \ , \\ T &\simeq \frac{2\times 10^{-7}}{G} \ . \end{aligned} \tag{6.1}$$

T is the string tension of the cosmic string. k is some numerical constant not too far from unity. The numerical study of the *ordinary* cosmic strings [E15] gives support for this order of magnitude estimate.

Taking the age of the Universe to be $a \sim 10^{11}$ years and assuming that the cosmic string is split in early phase of cosmology, the length of the portion of the decayed string is of the order

$$L \sim kTGa \simeq 2\times 10^4 k \ \text{light years} \ , \tag{6.2}$$

which is of the same order of magnitude as the typical size of the visible part of the galaxy.

An estimate for the rate of the energy production by single cosmic string is given by

$$P \sim Tv = kT^2G \sim \frac{4\times 10^{-14}k}{G} \sim 10^{47}k \times m(proton)/sec \ . \tag{6.3}$$

The energy production in quasars is roughly 10^{14} times larger than the energy production in Sun, which is about 10^{25} W: this gives $P \sim 10^{49} m_p/sec$. In order to have same order of magnitude one should have

$$k \sim 25 \ . \tag{6.4}$$

The required value of k looks suspiciously large and suggests that the energy flux from the decaying cosmic string could well be a jet directed to a narrow cone, which would increase the observed effective energy flux.

6.2 Decaying Cosmic String Ends As A Central Engine

It seems that the decaying cosmic string could explain elegantly the basic properties of the central engines. There are two alternative scenarios to be considered.

I) Galaxies are formed around the ends created in the splitting of a very long cosmic string.

II) Galaxies are formed by a decay of a piece of cosmic string. The decay of a finite piece of cosmic might explain the existence of some stellar objects accompanied by jet like structures.

In both cases the rate of the string decay gives a correct upper bound for the recent size of the visible part of the galaxies. Consider now the explanation of basic characteristics of active galaxies.

1. Visible jets are created by the energy beams

   The rate of the energy production in the decay of a cosmic string is few per cent about the estimated energy production in quasars assuming spherical symmetry. A correct rate for the observed energy flux from quasars is obtained if the energy from the decay of the string is liberated in a jet. Since two string ends are involved, the visible two-jet structure is an automatic consequence. The jets emerging from the active galactic nuclei are created by the interaction of the primary jets with the ordinary matter.

2. Quasars.

   Quasars differ from the ordinary galaxies only in that the energy jet from the cosmic string decay meets Earth. This explains the non-thermal nature of the spectrum and the absence of the atomic lines for the most intensive quasars (they are masked by the primary radiation). The rapid variations (a time scale of an hour) in the luminosity can be understood as resulting from the motion of the cosmic string inducing changes in the direction of the jet. Also the similarity between active and inactive galaxies is an automatic consequence.

3. Active-inactive distinction.

   For the option I possible explanation is that the galactic black hole has absorbed all matter around the galaxy and the jets coming from the decay of the cosmic strings have nothing with which to interact. It could however happen that the two jets interact with matter in very distant regions creating two tightly correlated jets but apparently originating from very distant sources. It could also occur that string ends are inside a galactic black hole for inactive galaxies so that the decay products remain inside the black hole and no visible jets are created. For the option II inactive galaxies without any jets, one can also consider the possibility that the piece of cosmic string has already decayed completely.

4. Dark matter halo.

   There are two alternative explanations for the velocity spectrum of the distant stars around the galaxy. The first, purely TGD based, explanation is that distant stars are gravitationally bound to the rotating cosmic string. Cosmic string indeed rotates with a correct velocity and, being Kähler charged, creates a genuine gravitational field unlike neutral cosmic string. The standard explanation is based on the assumption that galaxy is surrounded by a dark matter halo.

   An interesting possibility is that a halo of dark matter could result from the decay of the cosmic strings, perhaps in the form of ordinary and exotic neutrino like matter predicted by TGD. The decay could produce also part of the visible matter around the galactic nucleus. The jet model suggests that most of the decay products of the cosmic string escape the visible region of the galaxy but massive and Kähler charged particles with a proper sign of charge could remain bound to the cosmic string. Dark variants of ordinary elementary particles, in particular dark neutrinos, suffer classical Z^0 force below appropriate p-adic length scale. Clearly, Kähler force favors the generation of matter antimatter asymmetry. The average density in the halo would however be perhaps too small to explain the velocity spectrum.

5. Production mechanism for ultrahigh energy cosmic rays.

   The decay of the cosmic string should also give rise to ultrahigh energy cosmic rays. This production mechanism would provide an alternative for the production mechanisms based on the acceleration of the charged particles [it is difficult to conceive how any acceleration mechanism could lead to the generation of ultra high energy cosmic rays].

6.3 How To Understand The Micro-Jet Structure?

The long jets with length of roughly 10^6 light years have microstructure consisting of micro-jets with length of order one light year. This feature could be regarded as a shortcoming of the model. A possible TGD based explanation is based on lense effect on the gravitational field of the split cosmic string (scenario I).

In option I, a lense effect, caused by the strong gravitational field of the cosmic string itself, and creating multiple images could be involved. Since charged cosmic string is in question, the situation is more complicated than for the ordinary cosmic string. For instance, photon could rotate several times around the cosmic string before leaving the galactic region. The disappearance of the effect in distant regions (of length of order light year) could be understood if the energy jet were on the wrong side of the string at large distances or the distance between the jet and cosmic string would become so large that photons would not anymore circulate around the string.

6.4 Gamma-Ray Bursts And Cosmic Strings

Gamma ray bursters [E33] are now quite generally believed to have a cosmological origin. The energy flux from the gamma ray bursters (assuming spherical symmetry and cosmological origin and distance of order 10^8 ly) is about 10^{16} times the energy flux from Sun and by a factor of 10^2 larger than the total energy flux from the decaying cosmic string. The order of magnitude is same as for the energy flux of quasars. Typically the energy is produced in pulses lasting for a few seconds but also long lasting bursts consisting of a train of smaller pulses with a duration of order second are detected. It seems that the system emitting pulses is in some sense near criticality. The distribution of the gamma ray bursters is isotropic.

An interesting possibility is that decaying cosmic strings might explain also this phenomenon. The string would produce a continuous stream of energy, which fails slightly to meet Earth. Small perturbations causing the string end to oscillate (random oscillation of the direction of a flicker is a good analogy) imply that the beam of energy can meet the Earth at each period of oscillation and cause a sequence of pulses. A unique maximum intensity is predicted.

The shape of the pulse is predicted to reflect only the time development of the direction of the cosmic string rather than the actual intensity distribution of the pulse and this should make it possible to distinguish between TGD based and other explanations for the bursts. For instance, the typical bi-modality of the pulse could reflect directly to a perturbation taking string direction from the equilibrium position and bringing it back. The asymmetry of this perturbation caused by dissipative effects should explain the asymmetry of the two intensity peaks. The observed hardness-brightness correlation could be understood as following from the cosmic red shift and cosmic time dilatation increasing the observed duration of the pulse.

From the estimate that there are

$$\frac{dN}{dt} \sim 10^{-6}\ year^{-1}\ galaxy^{-1}$$

bursts per galaxy per year and taking the average duration t_P of the pulse to be

$$t_P \sim 1\ sec\ ,$$

one obtains a *very* rough estimate for the probability that a given galaxy acts as a gamma ray burster at a given moment as

$$P \sim t_P \times \frac{dN}{dt} \sim 10^{-13}.$$

One can estimate the solid angle Ω of the cone to which the energy of the decaying cosmic string is emitted: the probability P for galaxy being a burster, is simply the product of the probability $p(A)$ that galaxy is active multiplied with the probability $\Omega/(4\pi)$ that Earth happens to be in the solid angle Omega

$$P = \frac{p(A)\Omega}{4\pi} \sim 10^{-13} \ ,$$

which gives

$$\Omega \sim \frac{4\pi P}{p(A)} \sim \frac{10^{-12}}{p(A)} \ .$$

To proceed further an estimate for the probability of being active galaxy is needed. The value of Ω had better to be rather small since the oscillations in the direction of the cosmic string leading to fluctuations in the intensity of beam must be of the order of Ω and too large fluctuations are not expected (cosmic string is quite a heavy object!).

7 The Light Particles Associated With Dark Matter And The Correlation Between Gamma Ray Bursts And Supernovae

Both the model for dark matter identified as cosmic strings or their decay products and the model for gamma ray bursts identified as beams resulting in the fire cracker like decay of cosmic strings were constructed more than decade ago. During year 2003 came several astonishing observations, which at first seemed to be in a dramatic conflict with both the model of the dark matter and the model of gamma ray bursts.

It however turned out that these findings allow to relate, modify, and generalize as many as five models sketched at that time as the first applications of TGD. The subjects modeled were following:

1. The final state of a rotating star predicting flux tube like magnetic field along the symmetry axis [K16].

2. Dark matter identified as cosmic strings or their decay products.

3. Sunspots identified as the throats of magnetic flux tubes feeding magnetic flux to larger space-time sheet and behaving effectively as magnetic monopoles [K10]).

4. Gamma ray bursts explained as cosmic firecrackers resulting from the decay of split cosmic strings to elementary particles.

5. The anomalous e^+e^- pairs produced in the collisions of heavy nuclei at energy near the Coulomb wall as decay products of lepto-pions consisting of color excited leptons [K15].

7.1 Correlations Between Gamma Ray Bursts And Supernovae

The established correlation between gamma ray bursts and supernovae is certainly the cosmological discovery of the year 2003 [E22, E26].

1. The first indications for supernova gamma ray burst connection came 1998 when a supernova was seen few days after the gamma ray burst in the same region of sky. In this case the intensity of the burst was however by four orders of magnitude weaker than for the typical gamma ray bursts so that the idea about the correlation was not taken seriously. On 29 March, observers recorded a burst christened as GRB030329. On 6 April, theorists at the Technion Institute of Technology in Israel and CERN in Geneva predicted that there would

be signs of a supernova in the visible light and infrared spectra on 8 April [E22]. On cue, two days later, observers picked up the telltale spectrum of a type Ic supernova in the same region of sky, triggered as the collapsing star lost hydrogen from its surface. It has now become clear that a large class of gamma ray bursts correlate with supernovae of type Ib and Ic [E14], and that they could thus be powered by the mere core collapse leading to supernova. Recall that supernovae of type II involve hydrogen lines unlike those of type I. Supernovae of type Ib shows Helium lines, and Ic shows neither hydrogen nor helium but intermediate mass elements instead. Supernovae of type Ib and Ic are thought to result as core collapse of massive stars.

2. One of the most enigmatic findings were the "mystery spots" accompanying supernova SN1987A at a distance of few light weeks at the symmetry axis at opposite sides of the supernova [E27]. Their luminosity was nearly 5 per cent of the maximal one. SN1987A was also accompanied by an expanding axi-symmetric remnant surrounded by three concentric rings.

3. The latest finding [E20] is that the radiation associated with the gamma ray bursts is maximally polarized. The polarization degree is the incredible 80 ± 20 per cent, which tells that it must be generated in an extremely strong magnetic field rather than in a simple explosion. The magnetic field must have a strong component parallel to the eye sight direction.

7.1.1 Do topologically condensed cosmic strings become co-moving magnetic flux tubes serving as seeds for the formation of stars and galaxies

According to the model for the formation of stars and galaxies proposed already fifteen years ago, topologically condensed pieces of cosmic strings perhaps resulting in the collision of long possibly knotted cosmic strings would serve as seeds making possible formation of lumps of matter forming later stars. The assumption that the pieces of cosmic strings result in the collision of cosmic strings leading to the splitting of them to pieces with some fractal length distribution perhaps concentrated around p-adic length scales would explain why the mass $M(R)$ of galactic dark matter inside a sphere of radius R is proportional to the radius: $M(R) \propto R$.

1. Topologically condensed cosmic strings as co-stretching magnetic flux tubes

I considered already 15 years ago a model for topological condensation of cosmic strings assuming that strong radial Kähler electric fields are generated to compensate the large positive magnetic action. Cosmic strings are actually a special case of magnetic flux tube solutions of field equations. This leads to a revised vision for what happens for topologically condensed cosmic strings. This model does not exclude the presence of the radial electric fields due to the charging of the cosmic strings.

Cosmic strings, which are in the ideal situation string like objects of type $X^2 \times Y^2$, X^2 string like object in M^4_+ and Y^2 geodesic sphere of CP_2 or a piece of it, generate an M^4_+ projection which increases in thickness so that the solution becomes increasingly thicker magnetic flux tube. In the topological condensation the open ends of the string disappear and thus no decay to elementary particles can occur. Thus the topological condensation would stabilize the cosmic strings against decay.

1. The simplest assumption is that the topologically condensed piece of a magnetic flux tube of finite length co-stretches with the expanding universe so that its length increases as $L \propto a$, a light cone proper time.

2. The requirement that magnetic flux is conserved and quantized implies $B \propto 1/S$, S the transverse area of the flux tube. The condition that magnetic energy is conserved, implies $S \propto L \propto a$ and $B \propto 1/a$. This of course applies both to the magnetic and Z^0 magnetic flux tubes.

The assumption that topologically condensed pieces of cosmic strings remain co-stretching forever is questionable, and it might be that when the thickness of the flux tube reaches a critical value corresponding to a Compton length of say pion or lepto-pion, expansion stops, and the flux tube freezes to a very long hadronic or lepto-hadronic (color) magnetic flux tube (a Kähler field giving rise to em or Z^0 field gives also rise to a classical color field).

"Wormhole magnetic fields" consist of pairs of magnetic flux tubes represented by space-time sheets with opposite time orientations and thus having opposite energies. These structures have zero energy and I have proposed that they play a key role in the physics of living matter. In particular, they could be generated by intentional action by first generating a p-adic variant of the wormhole magnetic field representing the intention to generate wormhole magnetic field, and then transforming it to its real counterpart in quantum jump. One cannot exclude the possibility that cosmic strings could also be generated as zero energy pairs of cosmic strings with opposite time orientation. This would make possible to intentionally create universe from nothing. This is actually the only possibility if one poses the boundary condition that no quantum numbers flow out of the future light cone at its boundary.

2. Stars and galaxies as gravitational condensates around fragments of cosmic strings

The gravitational condensation of matter around short parallel flux tubes topologically condensed at larger space-time sheets is a natural mechanism for generating structures like galaxies and stars. The pieces of magnetic flux tubes would form expanding ferro-magnet like structure in the self-consistent magnetic field defined by the by the return flux flowing at the space-time sheet at which strings have suffered topological condensation. The contribution of the magnetic flux tubes to the total mass of the star can be small and the ordinary matter can be seen as decay products of cosmic strings as in the earlier model. Similar mechanism with different initial length of topologically condensed cosmic strings and resulting in fragmentation in the collision of say two long cosmic strings could give rise to the birth of galactic nuclei.

According to the TGD based model of primordial critical cosmology, the transition from string dominated to radiation dominated cosmology should have occurred at $a_0 \sim 10^{-10}$ s, and one could argue that the topological condensation of the magnetic flux tubes should have started at this time. With this assumption the recent thickness of the magnetic flux tubes would be $d = (a/a_0)^{1/2} \times 10^4\sqrt{G} \sim 10^{-16}$ m for $a \sim 10^{11}$ years. This corresponds to a hadronic length scale. Quite generally, this would suggest that at light cone proper time a the fragments of long cosmic strings, which have survived the decay to elementary particles, have typical length $L \sim a$.

From the recent length of about light month associated with super nova SN1987A (identifying the mysterious light spots as ends of the flux tube), one can deduce that the length L_0 of the cosmic strings at a_0 would have been $L_0 \simeq 10^{-14}$ m, roughly the Compton length of pion. The corresponding magnetic field would be about 10^{16} Tesla and extremely strong. Fields of similar magnitude have been proposed to result in the core collapse of supernovae [E16]. It however seems that the flux tubes of the primordial magnetic fields cannot explain the highly polarized synchrotron radiation but that the temporary extremely strong Z^0 magnetic field induced by the core collapse are responsible for the polarization.

Magnetic and Z^0 magnetic flux tubes as templates for the formation of material structures is an idea borrowed from TGD inspired theory of consciousness and of bio-systems as macroscopic quantum systems [K13]. The TGD based quantum model for bio-matter assumes that the magnetic flux tubes of Earth serve as templates for the formation of bio-matter, and also define what I have called magnetic bodies controlling pre-biotic and biotic evolution [**?**]. Also the idea that magnetic flux tubes act as wave guides and make precisely targeted communications possible originates from TGD inspired theory of consciousness [**?**]. Thus magnetic flux tube structures could serve as templates for and even guide the evolution of matter in all length and time scales: this is certainly in spirit with the fractality of TGD Universe.

7.1.2 A mechanism producing gamma ray burst and polarized synchrotron radiation

The dynamo model for the final state of a rotating star leads to a model for gamma ray bursts consistent with ultrahigh polarization of the synchrotron radiation. The model is consistent with the standard model for the radiation beams from neutron stars.

1. Generalizing the dynamo model for the final state of rotating star

TGD based dynamo model for the final state of rotating star predicts that the rotation axis star contains extremely strong magnetic or Z^0 magnetic field. The field along the axis can also be helical and B_ϕ would naturally result from the rotation of the matter. While attempting to interpret the dynamo model I proposed that the axial field might somehow relate to a cosmic string. This might be indeed the case.

What I did not realize 15 years ago that many-sheeted space-time allows both magnetic and Z^0 magnetic dynamo fields and their symmetry axes of the fields need not coincide.

1. The atomic nuclei of even ordinary condensed matter can carry anomalous weak charges due to the presence of color bonds between nucleons having at their ends exotic quarks with mass of order electron mass and carrying also weak charges [K12, K4]. If some color bonds become charged they have also net weak charges. The Z^0 repulsion due to the weak bosons with Compton length of order atomic radius can explain the low compressibility of condensed matter and give rise to the repulsive term in van der Waals equation. Weak repulsion due to exotic weak bosons is expected to become important in the extremely dense phase of matter inside star.

2. There are good justifications for the assumption that Z^0 magnetic axis is parallel to the rotation axes- Z^0 magnetic field having neutron number as its source receives a large varying contribution dictated by the flow dynamics of the star. Hence Z^0 magnetic field is expected to be very strong, at least in the situations in which currents of different dark matter particle species do not cancel each other. In particular, the ejection of dark neutrinos during the formation of supernova is expected to generate a strong Z^0 charge due to the anomalous Z^0 charges of nuclei. This induces both Z^0 electric field and Z^0 magnetic fields. Since rotation and Z^0 magnetic fields are so strongly coupled, the Z^0 magnetic and rotation axes should coincide.

3. The fact that the rotation axis of the star is rather stable is consistent with the primordial origin of the Z^0 magnetic field and suggests that Z^0 magnetic field as the primordial cause of the rotation.

4. Magnetic axis need not coincide with the rotation axis. The direction of the magnetic field of the star can be reversed (this is happening just now in case of Sun). This suggests that magnetic field does not have primordial origin and reflects the dynamics of the star.

5. TGD based variant for charged particle currents frozen to the magnetic field lines (assumed to have infinity conductivity in magnetohydrodynamics) are non-dissipative supra currents flowing along magnetic flux tubes of the magnetic and Z^0 magnetic fields. These currents in turn generate magnetic and/or Z^0 magnetic fields with field lines circulating around the rotation axes and thus make the magnetic field along symmetry axis helical.

6. Both in the case of magnetic or Z^0 magnetic field, the charged particles topologically condensed at the super-conducting flux tubes could be also spin polarized and amplify the field further.

In many-sheeted space-time topologically condensed magnetic flux tubes must feed their fluxes to larger space-time sheets so that a many-sheeted variant of the dipole field would result. The return fluxes would flow at larger space-time sheet and correspond to thicker flux tubes with weaker intensity of the magnetic flux. The regions, where the flux would be transferred between space-time sheets could correspond to flux tubes or wormhole contacts. In the latter case they would look like magnetic charges. As the in case of the sunspots, a fractal structure containing flux tubes inside flux tubes is expected [K10].

The mysterious light spots associated with SN1987A [E27] could correspond to flux tubes or the throats of the magnetic flux tubes of or primordial Z^0 magnetic flux tubes.

3. Synchrotron radiation in strong Z^0 magnetic field as a mechanism generating strong polarization

Usually the degree of polarization for the radiation from supernovae is around few per cent [E36]. The polarization associated with gamma ray burst GRB021206 is however incredibly high 80 ± 20 per cent and maximal polarization of the radiation [E20]. This requires extremely strong Z^0 magnetic field. The helical Z^0 magnetic field along the rotation axis can have flux quanta of astrophysical size and is ideal for accelerating dark charges flowing along the rotation axis and for producing dark photon synchrotron radiation leaking out in the direction of the rotating magnetic axis and transforming to ordinary photons by a mechanism analogous to de-coherence of laser beams [K4, K3]. Gamma ray bursts could be seen as a particular case of this radiation resulting when an especially strong dark current (say dark electron current) flows along the rotational axis in an exceptionally strong dynamically generated Z^0 magnetic field, and induces a beam of synchrotron radiation along the rotating magnetic axis.

The radiation is linearly polarized with the polarization direction and intensity defined by the vector

$$\overline{n} \times (\overline{n} \times \overline{B}^Z) = \overline{B}^Z - B_z^Z cos(\theta)\overline{n} \ ,$$

where $\overline{n}$ is the direction of the observer in the direction of the axial magnetic flux tubes and characterized by the angle θ. The direction of polarization is constant during the observation period if the symmetry axis associated with B^Z coincides with the rotation axis. It is essential that magnetic and Z^0 magnetic fields are not parallel and reside at different space-time sheets. The intensity is proportional to the square of the polarization factor given by

$$(B^Z)^2 \times \left(1 - cos^2(\alpha)cos^2(\theta)\right) \ , \quad cos(\alpha) \equiv \frac{B_z^Z}{B^Z} \ .$$

If the Z^0 magnetic field has only z-component, the intensity is proportional to $(B^Z)^2 sin^2(\theta)$ and at minimum.

4. Radial compression as a mechanism producing strong Z^0 magnetic field

A sudden compression in radial directions orthogonal to the rotation axis at the core collapse could be seen as a process analogous to the squeezing of the tooth paste tube. A strong non-dissipative supra current along the axis of magnetic field is induced because this is the route of the lowest resistance. This current in turn generates a strong magnetic field component B_ϕ^Z, and the charges accelerated in the axial direction in this field emit synchrotron radiation with a direction of polarization tangential to the magnetic field component B_ϕ^Z. If all nuclei possess anomalous Z^0 charges, the matter flow along rotation axis can generate very strong Z^0 magnetic field so that there are good hopes of explaining the anomalously high value of polarization of the synchrotron radiation.

The three expanding ring like structures associated with SN1987A [E4] could be identified as being due to dark Z^0 currents rotating around the strong axial Z^0 magnetic field. Even the identification as torus like flux quanta of Z^0 magnetic field induced by the very strong Z^0 current along the z-axis is possible. This kind of Z^0 magnetic dark currents rotating around axial Z^0 magnetic field could be even responsible for the rings associated with planets like Saturnus and even with the ring current associated with Earth. This picture conforms with the model for the formation of solar system in which macroscopically quantum coherent dark matter serves as a template around which ordinary matter is condensed [K10, K3] as also with the explanation of tritium beta decay anomaly assuming that Earth's orbit is surrounded by dark neutrino belt [K12].

It is known that spherical and even axial symmetry is broken in case of SN1987A and this is consistent with the fact that magnetic and Z^0 magnetic axis are not parallel. Let L be the line of sight orthogonal to the plane S of sky, and R the projection of the ring to S. Let z-axis correspond to L and x- and y-axis to the directions of the minor and major axis of R. Denote by E_z and E_y the projections of ejecta to S and xz-plane. From the figure 2 of [E28] one can deduce that the plane of the ring forms an angle of 44 degrees with respect L. The symmetry axes of E_y resp. E_z forms an angle of 45 degrees resp. 15 degrees with respect to x-axis. From this one can conclude the polar and azimuthal angles of the symmetry axis of ejecta are $\theta = 45.4$ degrees and $\phi = 9$ degrees. A good guess is that this axis corresponds to the rotation axis and axis of Z^0 magnetic field tilted by 45.4 degrees with respect to the line of sight parallel to the magnetic axis. Mystery spots are known to be located at this axis too [E28] so that they could indeed correspond to sunspot like throats at which Z^0 magnetic flux is transferred between space-time sheets.

7.1.3 Magnetic flux tubes as wave guides

Magnetic flux tubes are ideal wave guides forcing the confined radiation to propagate in a precisely targeted manner along them. Topological light rays (MEs) accompany magnetic flux tubes involved and have interpretation as space-time correlates for a radiation propagating in the waveguide defined by the magnetic flux tube. They are accompanied by coherent light generated by light like vacuum currents associated with then. Topological light rays would couple to Alfven waves representing transversal oscillations of the magnetic flux tubes propagating also with light velocity.

The wave guide function of magnetic flux tubes suggests a generalization and modification of the model of gamma ray bursts. Gamma ray bursts would be generated by the synchrotron radiation generated in the acceleration of charges when they move along rotation axis with dynamically generated component B^Z_ϕ. Part of the resulting radiation would end up to a rotating magnetic flux tube bundle in the direction of the rotating magnetic axis. The initial channeling at the magnetic flux tubes would force synchrotron radiation to propagate to distant parts of the universe in a precisely targeted manner. This mechanism would explain the observed universal properties for the gamma ray [E33] [E21] difficult to understand in the models involving mergers, say collisions of white dwarf binaries [E14]. As already noticed, the model is consistent with the existing model for the ordinary radiation arriving from supernovae and thought of as involving a beam rotating with the supernova.

7.1.4 Gamma ray bursts as dark photons

In [K10] a model for dark graviton with a large value of Planck constant is developed. This yields also a model for the de-coherence of dark graviton and for what happens in the detection of dark gravitational radiation. The model applies also to dark gauge bosons.

1. The basic new element is that dark bosons are associated with topological light rays which are N-sheeted multiple coverings of M^4. The energy absorbed in the detection of a dark boson would be N-fold whereas the frequency for detections is expected to be $1/N$ times lower so that in average sense dark bosons would behave like normal ones. The events in which dark gravitons with large N are detected would be interpreted as noise. Same could apply to other dark bosons. Dark matter would be only apparently dark.

2. The propagation of of dark boson can be regarded as a sequential de-coherence in which pieces with smaller value of Planck constant and thus smaller energy are split off from the original dark boson. Frequency is not altered in this process.

   Gamma ray bursts could correspond to dark photons with very large value of N so that strongly targeted and very intense beam of ordinary photons results in the de-coherence process.

7.1.5 Gamma ray bursts as collective transitions of cosmic strings identified as scale up hadrons

According to the TGD based model [K8], hadrons consists of two kinds of matter. Valence quark space-time sheets have fused to single structure by color bonds, the "Pomeron" of the physics before QCD. This structure is in turn connected by bonds (possibly carrying the color of sea quarks) to string like hadronic space-time sheet characterized by Mersenne prime M_{107} and containing super-symplectic bosons giving the dominating contribution to the mass of light baryons.

The black-hole like characteristics of the hadronic space-time sheet, which conform with the experimental findings at RHIC, plus the general vision about the formation of neutron stars and quark stars via the fusion of hadronic space-time sheets encourage a generalization to a model for the microscopic structure of black-holes as highly tangled strings inside black-hole horizon. Black-hole would be kind of scaled up hadron.

The Mersenne primes characterizing the hadronic space-time sheet in the hierarchy extending from cosmic strings to hadrons would belong to the set $\{M_n|vertn = 2, 3, 5, 7, 13, 17, 19, 31, 61, 89, 107\}$. The quarks contained by cosmic string would be labeled by rather small p-adic primes. Cosmic strings would give rise to primordial black-holes decaying to ordinary matter and magnetic flux tubes with a lower string tension. Gamma ray bursts could result in collective quantum transitions of cosmic strings involving several steps with end products of final state at each step characterized by a smaller Mersenne prime. For gamma ray bursts produced by super-novae the value of Mersenne prime would be probably $k = 107$.

Note that ordinary hadrons need not define the lowest level of the hierarchy since also M_{127} copy of hadron physics appears in the TGD based model of nucleus. If Gaussian Mersennes are allowed then much more levels are possible: in particular, in length scale range especially relevant for living systems.

7.1.6 Gamma ray bursts and quantum phase transitions in the scale of string like object

The model of hadrons behind hadronic mass calculations leads to the vision that super-symplectic bosons are responsible for the most of hadronic mass [K8, K7]. This in turn leads to a microscopic model for neutron stars, quark stars, and black-holes as highly entangled hadronic strings resulting in the fusion of hadronic strings. Also cosmic strings would contain super-symplectic matter and separate from environment by black hole horizon.

All these objects would be macroscopic quantum systems and their quantum transitions could generate dark gamma rays, dark gravitons, and other dark particles decaying to ordinary particles in de-coherence phase transition.

A model for dark graviton emission assignable to the gravitational quantum transition of astrophysical objects characterized by gigantic gravitational Planck constant is discussed in [K16]. Dark gravitons would correspond to pulses of ordinary gravitons resulting in de-coherence rather than continuous flow of gravitons. These pulses might be dismissed as noise in measurement philosophy based on standard quantum mechanics.

7.2 Lepto-Pions As A Signature Dark Matter?

The identification of cosmic strings as the ultimate source of both visible and dark matter does not exclude the possibility that a considerable portion of topologically condensed cosmic strings have decayed to some light particles. In particular, this could be the situation in the galactic nuclei. On the other hand, if some fraction of cosmic strings evolve to magnetic flux tubes, these flux tubes identifiable as dominant part of the dark matter can carry phases of some exotic particles serving as signatures of the dark matter. Quite recent experimental findings [E24] suggest that these exotic particles could be lepto-hadrons predicted by TGD [K15].

7.2.1 Two anomalies

The idea that lepto-hadrons might have something to do with the dark matter has popped up now and then during the last decade but for some reason I have not taken it seriously. Situation changed towards the end of the year 2003. There exist now detailed maps of the dark matter in the center of galaxy and it has been found that the density of dark matter correlates strongly with the intensity of monochromatic photons with energy equal to the rest mass of electron [E24].

The only explanation for the radiation is that some yet unidentified particle of mass very nearly equal to $2m_e$ decays to an electron positron pair or directly to gamma pair. Electron and positron are almost at rest and this implies a high rate for the annihilation to a pair of gamma rays. A natural identification for the particle in question would be as a lepto-pion. By their low mass lepto-pions, just like ordinary pions, would be produced in high abundance, in lepto-hadronic strong reactions and therefore the intensity of the monochromatic photons resulting in their decays would serve as a measure for the density of the lepto-hadronic matter. Also the presence of lepto-pionic condensates can be considered. Lepto-pions decay directly to both gamma pairs and electron-positron pairs. Indeed, galaxy is for long time known to be a source of positrons and there is no generally accepted mechanism producing them [E24].

The second anomaly was the microwave interstellar medium emission observed by WMAP used to map the anistropy of cosmic microwave spectrum [E23]. Unfortunately, the anomaly reached my attention for more than 4 years later. Anomalous lines at frequencies $f = 23; 33, 41, 61, 94$ GHz have been observed. In good approximation they correspond to harmonics of single frequency of f= 10 GHz. For the cyclotron transitions of electron the required magnetic field would be about

0.36 Tesla. The identification would be in terms of cyclotron transitions of dark electrons or of their Cooper pairs residing at magnetic flux tubes of galactic magnetic fields and characterized by so large value of Planck constant that cyclotron energy is above thermal energy. The emitted cyclotron radiation would decay into bunches of ordinary photons with same frequency but much smaller energy.

7.2.2 Lepto-hadron as explanation of gamma ray anomaly?

In the chapter [K15] I have discussed the TGD based explanation for the anomalous production of electron positron pairs in the collisions of heavy nuclei at energies corresponding to the height of Coulomb wall. The effect was observed for more than fifteen years ago [C2] but after string model revolution has been forgotten by theorists like many other anomalies of particle physics. The hypothesis is that so called lepto-pions are produced in the strong, non-orthogonal, and rapidly varying electric and magnetic fields of the colliding nuclei. Lepto-hadrons are color bound states of colored excitations of leptons predicted by TGD defining an asymptotically non-free QCD. Actually an entire hierarchy of non-asymptotically free QCD: s are allowed in TGD Universe.

These findings force to take seriously either the identification
a) of the dark matter as lepto-hadrons or
b) of lepto-pions as a signature of dark matter, which itself would be basically magnetic energy associated the with cosmic strings transformed to magnetic flux tubes in topological condensation. Of course, lepto-pions could correspond to only a small fraction of dark matter and one can quite well imagined that they are created in strong interactions of leptobaryons.

In fact, lepto-pions are not the only possibility. The TGD based model for tetra-neutrons [C1] [K12] is based on the hypothesis that mesons made of scaled down versions of quarks corresponding to Mersenne prime M_{127} (ordinary quarks correspond to $k = 107$) and having masses around one MeV could correspond to the color electric flux tubes binding the neutrons to form a tetra-neutron. The same force would be also relevant for the understanding of alpha particles.

7.2.3 Why lepto-hadrons cannot directly correspond to dark matter?

The identification of lepto-hadrons as dark matter raises several questions leading to the conclusion that lepto-pions are most probably only a signature of dark matter.

1. Why the ratio of the lepto-hadronic mass density to the mass density of the ordinary hadrons would be so high, of order 7? Could an entire hierarchy of asymptotically non-free QCDs be responsible for the dark matter so that lepto-hadrons would explain only a small portion of the dark matter? Is even the hierarchy of QCD: s enough?

2. Under what conditions one can regard lepto-hadronic matter as a dark matter? Could short life-times of lepto-hadrons make them effectively dark matter in the sense that there would be no stable enough atom like structures consisting of say charged lepto-baryons bound electromagnetically to the ordinary nuclei or electrons? But what would be the mechanism producing lepto-hadrons in this case (nuclear collisions produce lepto-pions only under very special conditions)?

3. What would be the role of the many-sheeted space-time: could lepto-hadrons and atomic nuclei reside at different space-time sheets so that lepto-baryons could be long-lived? Could dark matter quite generally correspond to the matter at different space-time sheets and thus serve as a direct signature of the many-sheeted space-time topology? Magnetic flux tubes are excellent candidates for the space-time sheets accommodate the dark matter but there are good reasons to believe that magnetic energy is considerably higher than the energy of particles condensed on magnetic flux tubes so that magnetic energy is the best candidate for dark matter.

These objections suggest that lepto-pions serve only as a signature of dark matter. The recent vision about dark matter suggests that all particles can appear as dark variants and reside at magnetic flux tubes and lepto-pions could be only particular kind of dark matter. Of course, dark matter itself could correspond also to the magnetic energy of the magnetic flux tubes and cosmic strings.

7.2.4 Lepto-pions topologically condensed on magnetic flux tubes as a signature of dark matter?

Lepto-pions and other lepto-hadrons producing copiously lepto-pions could reside at magnetic of Z^0 magnetic flux tubes of thickness of order Compton length of lepto-pion. These strings could be seen as kind of very long lepto-hadronic strings. Also long hadronic flux tubes carrying coherent states of ordinary pions are possible and Z^0 flux tubes beaming the gamma ray bursts could correspond to them.

One could identify the lepto-hadronic magnetic flux tubes as structures generated later in the cosmic evolution, when the magnetic flux of hadronic flux tubes flow to larger space-time sheets. The transversal length scales of the flux tubes would be in ratio m_e/m_p and the magnetic field would be by a factor of about 10^{-6} weaker, about 10^{10} Tesla whereas the magnetic field of supernovae are around 10^9 Tesla. If the thickness of the magnetic flux tube at the moment of the annihilation of lepto-pion is of the order of Compton length of electron, one obtains an estimate for its thickness at the moment when the transition to the radiation dominated phase occurred.

If the strength of the magnetic field is of order $eB \sim m_e^2 \sim 10^9$ Tesla, the cyclotron frequency would be of same order as electron mass $eB/m_e \sim m_e$ and in gamma ray region. For $eB \sim m_p^2$ the field strength would be 10^{15} Tesla and cyclotron energy would be of order proton mass. Harmonics of this line might serve as a signature for the strength of the magnetic field. The monochromatic gamma lines at electron mass could also result in cyclotron transitions of electrons if the magnetic field at magnetic flux tubes that $eB = m_e^2$ holds true in high precision.

One can imagine two mechanisms of lepto-pion production.

1. The magnetic and Z^0 magnetic fields associated with the magnetic flux tubes give rise to classical color fields, which suggest that one could regard the flux tubes as macroscopic color magnetic and possibly also color electric flux tubes carrying lepto-hadrons, which produce copiously lepto-pions in their reactions.

2. In heavy ion collisions lepto-pion production is caused by the presence of the rapidly varying non-orthogonal electric and magnetic fields of colliding nuclei, whose "instanton density" $E \cdot B$ is non-vanishing (this means that the magnetic flux tube has higher than 2-dimensional CP_2 projection). The amplitude for lepto-pion production as a decay of the coherent state is proportional to the Fourier component of the "instanton density". The mechanism could be at work also now if magnetic flux tubes carry strong charges and generate radial electric fields. Lepto-pions would serve as signature for rapid changes of the magnetic and electric fields induced by rapid deformations of the magnetic flux tubes.

7.2.5 Solar X-ray halo and scaled up QCDs at magnetic flux tubes

Quite recently New Scientist told about an explanation proposed by Kostantin Zioukas and his colleagues [E29] for the X-ray halo of Sun in terms of axions, one of the many candidates for the dark matter [E8]. The X-ray halo of Sun was detected at 1940. The halo extends from the surface of Sun (free path for photons increases at the surface). The X-ray intensity decays exponentially and extends several solar radii from the surface. The energy range of X-rays is $3-15$ keV. The origin of the X-ray halo has remained a mystery.

The axions in the required mass range are predicted by certain higher-dimensional theories [E29]. The axions would be produced in the solar core and because of their extremely long lifetime they would propagate to the surface of Sun and some fraction of non-relativistic axions would remain bound in the solar gravitational field where they would decay. The estimated mean distance of the proposed axion population from the solar surface is about 6.2 solar radii. Zioukas and his colleagues are able to deduce the value of the coupling constant $g_{A\gamma\gamma}$ characterizing the rate of axion decay and the interaction cross section of axion with matter from the fact that the X-ray luminosity must be proportional to $g_{A\gamma\gamma}^4$. The resulting lifetime of the axion is about 10^{21} s to be compared with the lifetime of ordinary pion about 10^{-16} s.

TGD suggests an alternative explanation based on a non-asymptotically free exotic QCD at a magnetic flux tube corresponding to a p-adic length scale $L(k)$ for which the scaled down value of pion mass corresponds to mass of about 3 keV. Assuming that pion corresponds to $k = 107$ ($k = 109$ is the second candidate) this gives $2^{(k-107)/2} \sim m_{\pi(107)}/m_{\pi(k)}$. The lower limit for the energy spectrum would favor the p-adic length scale $L(139)$ giving $m_{\pi(139)} \simeq 2.2$ keV. The lifetime of lepto-pion would be scaled up by a factor 2^{16} so that one would have $\tau \sim 10^{-11}$ s. One cannot exclude the presence of several scaled up QCDs with $k = 139, 137$ and $k = 131$ being the most favored ones in the energy range of about 3 octaves spanned by the X-ray spectrum.

In the recent case the intensity of the X-ray halo from a given spherical volume V of the halo defining the pixel is determined by the density $dn(\pi)/dl$ of the exotic pions per unit length of the magnetic flux tube and the length $l(V)$ of the magnetic flux tube inside the volume, which is expected behave as $l(V) \sim V^{1/3}$. A rough estimate is

$$I(V) \sim \frac{dn(\pi)}{dl} \times l(V) \times \Gamma \times \langle E(\pi) \rangle \Delta\Omega \ ,$$

where $\Delta\Omega = A/4\pi R^2$ is the solid angle defined spanned by the active detection area A of the measuring instrument at a given point of the magnetic flux tube and R is the distance of Earth from Sun. In principle this allows to estimate the density of exotic pions per unit length of the magnetic flux tube.

The exponential decay of the intensity with distance from the surface of the Sun would suggest that magnetic flux tubes might be regarded as threads extending from the solar surface and returning back to it, and that the probability of a path of given length decreases exponentially with its length. If the probability for the appearance of a thread of given length is proportional to the Boltzmann weight $exp(-E_B/T)$, where E_B is magnetic energy of the thread and T is temperature parameter, this indeed holds true.

The intensity of the magnetic field at the flux tubes can be estimated from the nominal value $B_E = .5 \times 10^{-4}$ Tesla of the Earth's magnetic field at the space-time sheet $k = 169$. By scaling one would obtain $B = 2^{169-139} B_E = 5 \times 10^4$ Tesla. The field is extremely strong and could be perhaps assigned to remnants of primordial cosmic strings. Note that also Z^0 magnetic field could be in question in which case dark matter coupling to scaled down copies of electro-weak bosons would be in question [**?**, K4].

7.2.6 Do the length scale ratios for astrophysical objects reflect Compton length ratios of elementary particles?

The ratio for the size $L_l \sim 10^5$ light years of a galactic nucleus to the distance $L_h \sim 1$ light month between the light spots of super nova gives an estimate for the ratio of the lengths of the lepto-hadronic and hadronic magnetic flux tubes. This would predict $L_l/L_h \sim 10^6$ and that the ratio of transverse thicknesses $d_l/d_h = 10^3$, which is the ratio of lepto-pion Compton length scale scale to proton Compton length. This would suggests that the length scale hierarchy for astrophysical objects could represent a scaled up version of the p-adic length scale hierarchy associated with elementary particles.

7.2.7 Frequency cutoff for zero point frequencies as a test for many-sheeted space-time?

For a quantum system mode lable in terms of harmonic oscillators (say photon field) the frequency spectrum in the thermal equilibrium obeys Planck distribution. Besides this the system exhibits zero point fluctuations whose energy density is given by $\rho_0(f) = 8\pi^2 f^3$ ($\hbar = c = 1$) in the 3-dimensional case. Zero point fluctuations appear in many models of physical phenomena such as X-ray scattering in solids, Lamb shift, Casimir effect, and the interpretation of the Aharonov Bohm effect (for references see [E17]).

The zero point fluctuations are predicted to appear also in electronic systems, and the experimentally measured spectral density of the current noise measured by Koch [E35] in Josephson junctions provides a direct support for this prediction. The fluctuations have been observed up to the frequency of $f = .6$ THz which corresponds to a microwave wavelength of .5 mm.

It has been proposed by Beck and Mackey [E17] that if these fluctuations are associated with the vacuum energy, the total vacuum energy density associated with these fluctuations cannot exceed the recently measured dark energy density of the Universe: this leads to a cutoff frequency of $f_c = (1.69 \pm .05)$ THz for the measured frequency spectrum.

In TGD framework dark matter is ordinary matter at larger space-time sheets. First of all, the finite size of the space-time sheet poses an IR cutoff. p-Adic length scale hierarchy suggests that there is also UV cutoff that corresponds to the next p-adic length scale in the hierarchy. Hence the frequencies above the UV cutoff would correspond to oscillations at smaller space-time sheets. The interpretation would be in terms of de-coherence.

Thus a given space-time sheet would contain half octave of frequencies between the frequency cutoffs $f_{low}(k) = c/L(k) \propto 2^{-k/2}$ and $f_{up}(k) = c/L(k+1)$. Cutoff frequencies would come as half octaves for k integer as predicted by the most general form of the p-adic length scale hypothesis. The stronger form of the hypothesis favors prime values of k. Note that for $k = 179$ (prime) the predicted cutoff frequency would be $f_c(179) \simeq 1.74$ THz, which happens consistent with the prediction of [E17] deduced from the estimate for the dark matter density. This need not be an accident. According to the TGD based model explaining the finding that neutrino mass depends on the environment, neutrinos can condense on several space-time sheets and neutrinos in dense matter travel along $k = 179$ space-time sheet [K6].

The problem is that the spectral density would be same at every space-time sheet. One might however hope that the shift of the spectrum from a space-time sheet to another one manifests itself as some kind of structure at half-integer octaves of a basic frequency. By using a suitable arrangement one might be even able to eliminate some space-time sheet so that a gap would result. An interesting question is how the measurement instrument could be constructed to detect only the frequencies associated with a space-time sheet corresponding to a fixed value of k.

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