Does the notion of gravastar make sense in the TGD Universe?

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Abstract

Gravastar provides an alternative view of blackhole-like objects. The density is constant inside the gravastar and there is no singularity at the origin. Interior has de-Sitter metric having constant density of dark energy with $\rho = -p$. The surface contains a layer of exotic matter moving with light velocity and having $\rho = p$. The exterior has Scwartschild metric. It came as a surprise that the TGD based model of blackhole-like objects and perhaps even of stars could be modelled as gravastars.

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1 Introduction

Mark McWilliams asked for my TGD based opinion about gravasta [E1] as a competing candidate for the blackhole (see this and this). The metric of the Gravastar model would be the de-Sitter metric in the interior of the gravastar. The density would be constant and there would be no singularity at the origin. The condition $\rho = -p$ would be true for de-Sitter and there would be analogy with dark energy, which in TGD framework contributes to galactic dark matter identified as classical volume and magnetic energies for what I call cosmic strings, which are 4-surfaces with string world sheet as M^4 projection. The condition $\rho = p$ would hold true for ultrarelativistic matter at the surface, which indeed as a light-like metric if the infinite value of the radial component g_{rr} of the Schwartschild metric is deformed to a finite value at the horizon. In the exterior one would have $\rho = p = 0$.

TGD suggests a model of a blackhole-like object as volume filling monopole flux tube tangle, which carries a constant mass density, which can be interpreted as dark energy as a sum of classical magnetic and volume energies. Quantum classical correspondence forces us to ask whether the description in terms of sequences of nucleons and in terms of classical energy are equivalent or whether the possibly dark nucleons must be added as a separate contribution. I have discussed the TGD based model of blackhole-like objects in [L3].

It became as a surprise for me that the gravastar could serve as a simple model for this structure and describe the space-time sheet at which the monopole flux tube tangle is topologically condensed. TGD also suggests that the surface of the star carries a layer of M_{89} matter consisting of scaled variants of ordinary hadrons with mass scale which is 512 times higher than that for ordinary hadrons. This would be the counterpart for the exotic matter and the surface of the gravastar [L3]. This model predicts that the nuclear fusion at the core of the star is replaced with a transformation of M_{89} hadrons to ordinary hadrons. This would explain the energy production of the star and also the stellar wind and question the structure of the interior. I have proposed that it could be a quantum coherent system analogous to a cell.

2 A TGD based model for the gravastar

Consider now the TGD counterpart of the gravastar model at quantitative level.

2.1 The realization of de-Sitter metric as a space-time surface

It became as a surprise that it is possible to realize de-Sitter metric as a space-time surface.

1. The metric of AdS_n (anti de-Sitter) *resp.* dS_n (de-Sitter) can be represented as space-like *resp.* time-like hyperboloid *resp.* of $n+1$-dimensional Minkowski space with one time-like dimension. The metric is induced metric

$$dx_0^2 - \sum_{i=1}^{n} dx_i^2 ,$$

with metric tensor deducible from the representation

$$x_0^2 - \sum_{i=1}^{n} x_i^2 = \epsilon\alpha^2 ,$$

as a surface. Here one has $\epsilon = -1$ AdS_n and $\epsilon = 1$ for dS_n.

It should be warned that the Wikipedia definition of the dS_n (see this) contains the right-hand side with a wrong sign (there is $\epsilon = -1$ instead of $\epsilon = 1$) whereas the definition of AdS_n (see this) is correct. For $n = 4$ this could realize AdS_4 *resp.* dS_4 as a space-like *resp.* time-like hyperboloid of 5-D Minkowski space.

2. In TGD this representation as surface is not possible as such. One can however compactify the 5:th space-like dimension and represent it as a geodesic circle of CP_2. dx_5^2 is replaced with $R^2 d\phi^2$ and x_5^2 with $R^2\phi^2$. The contribution of S^1 to the induced metric is very small since R corresponds to CP_2 radius. The space-time surface would be defined by the condition

$$a^2 = R^2\phi^2 + \epsilon\alpha^2 ,$$

where $a^2 = t^2 - x^2 - y^2 - z^2$ defines light-cone proper time a. In TGD it would be associated with the second half of the causal diamond (CD). A more convenient form is following

$$R^2\phi^2 = a^2 - \epsilon\alpha^2 ,$$

where a is the light-cone proper time coordinate of M^4. This requires $a^2 \geq \epsilon\alpha^2$. For $\epsilon = 1$ this implies $a^2 \geq \alpha^2$. For $\epsilon = 1$ one has $a^2 \geq -\alpha^2$ so that also space-like hyperboloids are possible.

3. If the embedding is possible, one obtains an infinite covering of S^1 by mass shells $a^2 = R^2\phi_n^2 + \epsilon\alpha^2$, where one has $\phi_n = \phi + n2\pi$. For $\phi \rightarrow \infty$ one has $a \rightarrow nR$. Hyperboloids associated with ϕ_n define a lattice of hyperboloids at this limit, a kind of time crystal.

4. If the classical action is Kähler action of CP_2, this surface is a vacuum extremal since the CP_2 projection is 1-dimensional. If also the contribution M^4 Kähler action to Kähler action suggested by the twistor lift of TGD is allowed, the situation the action is instanton action and vanishes although the induced M^4 Kähler form does not vanish and defines self dual abelian field. It is not quite clear whether this is vacuum extremal anymore.

   If the Kähler action vanishes, volume action is the natural guess for the classical action and minimal surface equations are indeed satisfied if S^1 is a geodesic circle. The mass density associated with this action would be constant in accordance with the de-Sitter solution.

5. Consider next the induced metric. One has

$$\phi_n = n2\pi + \sqrt{(a/R)^2 - \epsilon(\alpha/R)^2} \ .$$

   This gives $Rd\phi_n/da = \pm\ a/\sqrt{a^2 - \epsilon\alpha^2}$. Note that $a^2 \geq \epsilon\alpha^2$ is required to guarantee the reality of $d\phi/da$. The g_{aa} component of the induced metric (Robertson-Walker metric with $k = -1$ sub-critical mass density) is

$$g_{aa} = 1 - R^2(d\phi_n/da)^2 = 1 - a^2/(a^2 + \epsilon\alpha^2) = \epsilon\alpha^2/(a^2 + \epsilon\alpha^2) \ .$$

It is useful to consider AdS_4 and dS_4 separately.

1. For AdS_4 with $\epsilon = -1$, the reality of $d\phi/da$ implies $a^2 > -\alpha^2$ implying $g_{aa} < 0$ so that the induced metric has an Euclidean signature. This is mathematically possible and CP_2 type extremals with Euclidean signature are in an important role in the TGD based model of elementary particles. What Euclidian cosmology could mean physically, is however not clear.

2. For dS_4 with $\epsilon = 1$, $d\phi/da$ is real for $a^2 + \alpha^2 > 0$ implying $a^2 \geq -\alpha^2$. This allows all time-like hyperboloids and also some space-like hyperboloids. One has $g_{aa} = 1 - R^2(d\phi_n/da)^2 = 1 - a^2/(a^2 + \alpha^2) = \alpha^2/(a^2 + \alpha^2)$. g_{aa} is positive in the range allowed by the reality of $d\phi/da$.

3. The mass density of Robertson-Walker cosmology is obtained from the standard expression of the metric (note that one has $dt^2 = g_{aa}da^2$)is given by

$$\rho = \frac{3}{8\pi G}[(\frac{da/dt}{a})^2 - \frac{1}{a^2}] = \frac{3}{8\pi G}[\frac{1}{g_{aa}a^2} - \frac{1}{a^2}] = \frac{3}{8\pi G\alpha^2} \ .$$

   The mass density is constant and could be interpreted in terms of a dynamically generated cosmological constant $\Lambda = 3/\alpha^2$, whose invers has dimensions of length squared, in GRT framework. The value of Λ is positive and conforms with a positive vacuum energy energy density $\Lambda = 8\pi G\rho_{vac}$. This is not what happens usually in the Big Bang cosmology but would conform with a model of a star in an expanding Universe.

2.2 The physical interpretation in the TGD framework

Consider now the physical interpretation of de-Sitter space-time in the TGD framework.

1. In TGD, twistor lift predicts cosmological constant Λ with a correct sign [K3, K2]. The twistor lift of TGD predicts that $\Lambda = 3/\alpha^2$ is dynamical and has a spectrum. ρ corresponds to the volume term of the dimensionally reduced action having $\frac{3}{8\pi G\alpha^2}$ as coefficient. Also Kähler action is present contains CP_2 part and possibly also M^4 part.

   Λ is not a universal constant in TGD but depends on the size scale of the space-time sheet. The naive estimate is that it corresponds to the size scale of the space-time sheet associated with the system or its field body of the system, which can be much larger than the system.

   p-Adic length scale hypothesis suggests that apart from a numerical constant the scale $L_\Lambda = \sqrt{1/\Lambda}$ equals to the p-adic length scale L_p characterizing the space-time sheet. If p-adic length scale hypothesis $L(k) = \sqrt{p}$, where the prime p satisfies $p \simeq 2^k$, it implies $L(k) = 2^{(k-151)/2} \times L(151)$, $L(151) \simeq 10$ nm.

2. How does the average density of an astrophysical object or even smaller object relate to the vacuum energy density determined by Λ. There are two options: vacuum energy density corresponds to an additional contribution to the average energy energy density or determines it completely in which case one must assume quantum classical correspondence stating that the quantal fermionic contributions to the energy and other conserved quantum numbers are identical with the classical contributions so that there would be kind of duality. This would hold true only for eigenvalues of charges of the Cartan algebra.

3. One can assign to the cosmological constant a length scale as the geometric mean

$$l_\Lambda = \sqrt{l_P L_\Lambda} \ ,$$

where Planck length is defined as $l_P = \sqrt{\hbar G}$. One obtains therefore 3 length scales, Planck length, the big length scales L_Λ and their geometric mean l_Λ.

4. What is the relationship to the spectrum of Planck constants predicted by the number theoretical vision of TGD? If one replaces $\hbar$ with $\hbar_{eff} = nh_0$, one obtains a spectrum of gravitational constants G and of Planck length scales. CP_2 size scale $R \sim 10^4 l_P$ is a fundamental length scale in TGD. One can argue that G is expressible in terms of $R = l_P$ as $G_{eff} = l_P/\sqrt{\hbar_{eff}}$ and that the CP_2 length scale satisfies $R = l_P$ for the minimal value h_0 of h_{eff} so that one obtains $G_{eff} = R/\sqrt{\hbar_{eff}}$. For h_0 one obtains the estimate $h = (7!)^2 h_0$ in terms of Planck constant h. This would predict a hierarchy of weakening values of G.

   Note that $G = l_P/\sqrt{\hbar_{eff}}$ would predict the scaling $l_\Lambda \propto \hbar_{eff}^{1/4}$. Gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ for the system formed by large mass M and small mass m has very large values.

It is interesting to look at what values of l_Λ are associated with L_Λ , characterizing the size scale of a physical system or possibly of its field body.

1. For the "cosmological" cosmological constant one has $L_\Lambda \sim 10^{61} l_P$ giving $l_\Lambda \simeq 10^{31.5} l_P \simeq 2 \times 10^{-4}$ m. This corresponds to the size scale of a neuron. L_Λ could characterize the largest layer of its field body with a cosmological size scale.

2. A blackhole with the mass of the Sun has Scwartschild radius $r_S = 3$ km. $\Lambda = r_S$ gives $l_\Lambda \simeq 2.19 \times 10^{-16}$ m. The Compton length of the proton is $l_p = 2.1 \times 10^{-16}$ m. This estimate motivated the proposal that stellar blackholes could correspond to volume filling flux tubes containing a sequence of protons with one proton per Compton length of proton. This monopole flux tube would correspond to a very long nuclear string defining a gigantic nucleus. This result conforms with quantum classical correspondence stating that vacuum energy density corresponds to the density of fermions.

3. One can also look at what one obtains for the Sun with radius $R_S = 6.9 \times 10^8$ m, which is in a good approximation 100 times the radius $R_E = 6.4 \times 10^6$ m of the Earth. l_Λ scales up by the ratio $\sqrt{R_S/r_S}$ to $l_\Lambda \sim 5.7 \times 10^2 \times l_P \simeq 1.3 \times 10^{-14}$ m. This corresponds to a nuclear length scale and the corresponding particle would have a mass of about 17 MeV. Is it mere coincidence that there is recent very strong evidence (23 sigmas!) from the so called Ytterbium anomaly [C1] for so called X boson with mass 16-17 MeV [K1] [L1].

   The corresponding vacuum energy density $\hbar/\lambda^4$ would be about $8 \times 10^{38} m_p/m^3$. This is 12 orders of magnitude higher than the average density $.9 \times 10^{27} m_p/m^3$ of the Sun. Since $l_\Lambda \propto \sqrt{L_\Lambda}$ and $\rho \propto l_\Lambda^{-4} \propto L_\Lambda^{-2}$ one obtains $L_\Lambda \geq 10^{12} R_S \simeq 10^{20}$ m $\sim 10^5$ ly, which corresponds to the size scale of the Milky Way.

   The only reasonable interpretation seems to be that L_Λ characterizes the lengths of monopole flux tubes which fill the volume only for blackhole-like objects. The TGD based model for the Sun involves monopole flux tubes connecting the Sun with the galactic nucleus or blackhole-like object [L3]. In this case the density of matter at the flux tubes would be much higher since protons would be replaced with their M_{89} counterparts 512 higher mass. For this estimate, the vacuum energy density along flux tubes would be the average density of the

Sun. At least two kinds of flux tubes would be required and this is consistent with the notion of many-sheeted space-time.

The proposed solar model in which the solar wind and energy would be produced in the transformation of M_{89} nuclei to ordinary M_{107} nuclei allows to consider the possibility that the Sun and stars are blackhole-like objects in the sense that the interior correspond contains a volume filling flux tube tangle carrying vacuum energy density which is the average value of the solar mass density. I have considered this kind of model in [L2].

Could the scaling up the value of h to h_{eff} help to reduce the vacuum energy density assigned to the Sun? From $l_\Lambda \propto \hbar_{eff}^{1/4}$ the density proportional to $\hbar_{eff}/l_\Lambda^4$ does not depend on the value of h_{eff}.

To sum up, TGD could allow the interior of the gravastar solution as a space-time surface and this would correspond to the simplest imaginable model for the star. It is not clear whether Einstein's equations can be satisfied for some action based on the induced geometry but volume action is an excellent candidate even if cosmological constant is not allowed. In the TGD framework, the cosmological constant would correspond to the volume action as a classical action.

Schwartschild metric as exterior metric is representable as a space-time surface [K4] although it need not be consistent with any classical action principle and it could indeed make sense only at the quantum field theory limit when the many-sheeted space-time is replaced with a region of M^4 made slightly curved. The spherical coordinates for the Schwartschild metric correspond to spherical coordinates for the Minkowski metric and Schwartschild radius is associated with the radial coordinate of M^4. The exotic matter at the surface of the star as a blackhole-like entity could have a counterpart in the TGD based model of star [L3].

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