Inflation and TGD

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Abstract

The comparison of TGD with inflationary cosmology combined with new results about TGD inspired cosmology provides fresh insights to the relationship of TGD and standard approach and shows how TGD cures the lethal diseases of the eternal inflation. Very roughly: the replacement of the energy of the scalar field with magnetic energy replaces eternal inflation with a fractal quantum critical cosmology allowing to see more sharply the TGD counterpart of inflation and accelerating expansion as special cases of criticality. The rapid expansion periods correspond to phase transitions increasing the value of Planck constant and increasing the radius of magnetic flux tubes. This liberates magnetic energy and gives rise to radiation in turn giving rise to radiation and matter in the recent Universe just like the energy of inflaton field would give rise to radiation at the end of the inflation period in cosmic inflation. The multiverse of inflationary scenarios is replaced with the many-sheeted space-time and one can say that the laws of physics are essentially same everywhere in the sense that the fundamental symmetries are the symmetries of standard model everywhere.

1 Introduction

The comparison of TGD with inflationary cosmology combined with new results about TGD inspired cosmology provides fresh insights to the relationship of TGD and standard approach and shows how TGD cures the lethal diseases of the eternal inflation. Very roughly: the replacement of the energy of the scalar field with magnetic energy replaces eternal inflation with a fractal quantum critical cosmology allowing to see more sharply the TGD counterpart of inflation and accelerating expansion as special cases of criticality. Wikipedia gives a nice overall summary inflationary cosmology [1] and I recommend it to the non-specialist physics reader as a manner to refresh his or her memory.

2 Brief summary of the inflationary scenario

Inflationary scenario relies very heavily on rather mechanical unification recipes based on GUTs. Standard model gauge group is extended to a larger group. This symmetry group breaks down to standard model gauge group in GUT scale which happens to correspond to CP_2 size scale. Leptons and quarks are put into same multiplet of the gauge group so that enormous breaking of symmetries occurs as is clear from the ratio of top quark mass scale and neutrino mass scale. These unifiers want however a simple model allowing to calculate so that neither aesthetics nor physics does not matter. The instability of proton is one particular prediction. No decays of proton in the predicted manner have been observed but this has not troubled the gurus. As a matter fact, even Particle Data Tables tell that proton is not stable! The lobbies of GUTs are masters of their profession!

One of the key features of GUT approach is the prediction Higgs like fields. They allow to realize the symmetry breaking and describe particle massivation. Higgs like scalar fields are also the key ingredient of the inflationary scenario and inflation goes to down to drain tub if Higgs is not found at LHC. It is looking more and more probable that this is indeed the case. Inflation has endless variety of variants and each suffers from some drawback. In this kind of situation one would expect that it is better to give up but it has become a habit to say that inflation is more that a theory, it is a paradigm. When superstring models turned out to be a physical failure, they did not same thing and claimed that super string models are more like a calculus rather than mere physical theory.

2.1 The problems that inflation was proposed to solve

The basic problems that inflation was proposed to solve are magnetic monopole problem, flatness problem, and horizon problem. Cosmological principle is a formulation for the fact that cosmic microwave radiation is found to be isotropic and homogenous in an excellent approximation. There are fluctuations in CMB believed to be Gaussian and the prediction for the spectrum of these fluctuations is an important prediction of inflationary scenarios.

1. Consider first the horizon problem. The physical state inside horizon is not causally correlated with that outside it. If the observer today receives signals from a region of past which is much larger than horizon, he should find that the universe is not isotropic and homogenous. In particular, the temperature of the microwave radiation should fluctuate wildly. This is not the case and one should explain this.

   The basic idea is that the potential energy density of the scalar field implies exponential expansion in the sense that the "radius" of the Universe increases with an exponential rate with respect to cosmological time. This kind of Universe looks locally like de-Sitter Universe. This fast expansion smooths out any inhomogenities and non-isotropies inside horizon. The Universe of the past observed by a given observer is contained within the horizon of the past so that it looks isotropic and homogenous.

2. GUTs predict a high density of magnetic monopoles during the primordial period as singularities of non-abelian gauge fields. Magnetic monopoles have not been however detected and one should be able to explain this. The idea is very simple. If Universe suffers an exponential expansion, the density of magnetic monopoles gets so diluted that they become effectively non-existent.

3. Flatness problem means that the curvature scalar of 3-space defined as a hyper-surface with constant value of cosmological time parameter (proper time in local rest system) is vanishing in an excellent approximation. de-Sitter Universe indeed predicts flat 3-space for a critical mass density. The contribution of known elementary particles to the mass density is however much below the critical mass density so that one must postulate additional forms of energy. Dark matter and dark energy fit the bill. Dark energy is very much analogous to the vacuum energy of Higgs like scalar fields in the inflationary scenario but the energy scale of dark energy is by 27 orders of magnitude smaller than that of inflation, about 10^{-3} eV.

2.2 Evolution of inflationary models

The inflationary models developed gradually more realistic.

1. Alan Guth was the first to realize that the decay of false (unstable) vacuum in the early universe could solve the problem posed by magnetic monopoles. What would happen would be the analog of super-cooling in thermodynamics. In super-cooling the phase transition to stable thermodynanical phase does not occur at the critical temperature and cooling leads to a generation of bubbles of the stable phase which expand with light velocity.

   The unstable super-cooled phase would locally correspond to exponentially expanding de-Sitter cosmology with a non-vanishing cosmological constant and high energy density assignable to the scalar field. The exponential expansion would lead to a dilution of the magnetic monopoles and domain walls. The false vacuum corresponds to a value of Higgs field for which the symmetry is not broken but energy is far from minimum. Quantum tunneling would generate regions of true vacuum with a lower energy and expanding with a velocity of light. The natural hope would be that the energy of the false vacuum would generate radiation inducing reheating. Guth however realized that nucleation does not generate radiation. The collisions of bubbles do so but the rapid expansion masks this effect.

2. A very attractive idea is that the energy of the scalar field transforms to radiation and produces in this manner what we identify as matter and radiation. To realize this dream the notion of slow-roll inflation was proposed. The idea was that the bubbles were not formed at at all but that the scalar field gradually rolled down along almost flat hill. This gives rise to an exponential inflation in good approximation. At the final stage the slope of the potential would come so steep that reheating would took place and the energy of the scalar field would transform to radiation. This requires a highly artificial shape of the potential energy. There is also a fine tuning problem: the predictions depend very sensitively on the details of the potential so that strictly speaking there are no predictions anymore. Inflaton should have also a small mass and represent new kind of particle.

3. The tiny quantum fluctuations of the inflaton field have been identified as the seed of all structures observed in the recent Universe. These density fluctuations make them visible also as fluctuations in the temperature of the cosmic microwave background and these fluctuations have become an important field of study (WMAP).

4. In the hybrid model of inflation there are two scalar fields. The first one gives rise to slow-roll inflation and second one puts end to inflationary period when the first one has reached a critical value by decaying to radiation. It is of course imagine endless number of speculative variants of inflation and Wikipedia article summarizes some of them.

5. In eternal inflation the quantum fluctuations of the scalar field generate regions which expand faster than the surrounding regions and gradually begin to dominate. This means that there is eternal inflation meaning continual creation of Universes. This is the basic idea behind multiverse thinking. Again one must notice that scalar fields are essential: in absence of them the whole vision falls down like a card house.

The basic criticism of Penrose against inflation is that it actually requires very specific initial conditions and that the idea that the uniformity of the early Universe results from a thermalization process is somehow fundamentally wrong. Of course, the necessity to assume scalar field and a potential energy with a very weird shape whose details affect dramatically the observed Universe, has been also criticized.

3 Comparison with TGD inspired cosmology

It is good to start by asking what are the empirical facts and how TGD can explain them.

3.1 What about magnetic monopoles in TGD Universe?

Also TGD predicts magnetic monopoles. CP_2 has a non-trivial second homology and second geodesic sphere represents a non-trivial element of homology. Induced Kähler magnetic field can be a monopole field and cosmic strings are objects for which the transversal section of the string carries monopole flux. The very early cosmology is dominated by cosmic strings carrying magnetic monopole fluxes. The monopoles do not however disappear anywhere. Elementary particles themselves are string like objects carrying magnetic charges at their ends identifiable as wormhole throats at which the signature of the induced metric changes. For fermions the second end of the string carries neutrino pair neutralizing the weak isospin. Also color confinement could involve magnetic confinement. These monopoles are indeed seen: they are essential for both the screening of weak interactions and for color confinement!

3.2 The origin of cosmological principle

The isotropy and homogenity of cosmic microwave radiation is a fact as are also the fluctuations in its temperature as well as the anomalies in the fluctuation spectrum suggesting the presence of large scale structures. Inflationary scenarios predict that fluctuations correspond to those of nearly gauge invariant Gaussian random field. The observed spectral index measuring the deviation from exact scaling invariance is consistent with the predictions of inflationary scenarios.

Isotropy and homogenity reduce to what is known as cosmological principle. In general relativity one has only local Lorentz invariance as approximate symmetry. For Robertson-Walker cosmologies with sub-critical mass density one has Lorentz invariance but this is due to the assumption of cosmological principle - it is not a prediction of the theory. In inflationary scenarios the goal is to reduce cosmological principle to thermodynamics but fine tuning problem is the fatal failure of this approach.

In TGD inspired cosmology [6] cosmological principle reduces sub-manifold gravity in $H = M^4 \times CP_2$ predicting a global Poincare invariance reducing to Lorentz invariance for the causal diamonds. This represent extremely important distinction between TGD and GRT. This is however not quite enough since it predicts that Poincare symmetries treat entire partonic 2-surfaces at the end of CD as points rather than affecting on single point of space-time. More is required and one expects that also now finite radius for horizon in very early Universe would destroy the isotropy and homogenity of 3 K radiation. The solution of the problem is simple: cosmic string dominated primordial cosmology has infinite horizon size so that arbitrarily distance regions are correlated. Also the critical cosmology, which is determined part from the parameter determining its duration by its imbeddability, has infinite horizon size. Same applies to the asymptotic cosmology for which curvature scalar is extremized.

The hierarchy of Planck constants [3] and the fact that gravitational space-time sheets should possess gigantic Planck constant suggest a quantum solution to the problem: quantum coherence in arbitrary long length scales is present even in recent day Universe. Whether and how this two views about isotropy and homogenity are related by quantum classical correspondence, is an interesting question to ponder in more detail.

3.3 Three-space is flat

The flatness of three-space is an empirical fact and can be deduced from the spectrum of microwave radiation. Flatness does not however imply inflation, which is much stronger assumption involving the questionable scalar fields and the weird shaped potential requiring a fine tuning. The already mentioned critical cosmology is fixed about the value value of only single parameter characterizing its duration and would mean extremely powerful predictions since just the imbeddability would fix the space-time dynamics almost completely.

Exponentially expanding cosmologies with critical mass density do not allow imbedding to $M^4 \times CP_2$. Cosmologies with critical or over-critical mass density and flat 3-space allow imbedding but the imbedding fails above some value of cosmic time. These imbeddings are very natural since the radial coordinate r corresponds to the coordinate r for the Lorentz invariant a=constant hyperboloid so that cosmological principle is satisfied.

Can one imbed exponentially expanding sub-critical cosmology? This cosmology has the line element

$$ds^2 = dt^2 - ds_3^2 \ , \ \ ds_3^2 = sinh^2(t)d\Omega_3^2 \ ,$$

where ds_3^2 is the metric of the $a = constant$ hyperboloid of M^4_+ (future light-cone).

1. The simplest imbedding is as vacuum extremal to $M^4 \times S^2$, S^2 the homologically trivial geodesic sphere of CP_2. The imbedding using standard coordinates (a, r, θ, ϕ) of M^4_+ and spherical coordinates (Θ, Φ) for S^2 is to a geodesic circle (the simplest possibility)

$$\Phi = f(a) \ , \ \ \Theta = \pi/2 \ .$$

2. $\Phi = f(a)$ is fixed from the condition

$$a = sinh(t) \ ,$$

giving

$$g_{aa} = (dt/da)^2 = \frac{1}{cosh^2(t)}$$

and from the condition for the g_{aa} as a component of induced metric tensor

$$g_{aa} = 1 - R^2(\tfrac{df}{da})^2 = \tfrac{1}{cosh^2(t)} \ .$$

3. This gives

$$\frac{df}{da} = \pm\frac{1}{R} \times tanh(t)$$

giving $f(a) = (cosh(t) - 1)/R$. Inflationary cosmology allows imbedding but this imbedding cannot have a flat 3-space and therefore cannot make sense in TGD framework.

3.4 Replacement of inflationary cosmology with critical cosmology

In TGD framework inflationary cosmology is replaced with critical cosmology. The vacuum extremal representing critical cosmology is obtained has 2-D CP_2 projection- in the simplest situation geodesic sphere. The dependence of Φ on r and Θ on a is fixed from the condition that one obtains flat 3-metric

$$\frac{a^2}{1+r^2} - R^2 sin^2(\Theta)(\frac{d\Phi}{dr})^2 = a^2 \ .$$

This gives

$$sin(\Theta) = \pm ka \ , \ \ \frac{d\Phi}{dr} = \pm\frac{1}{kR}\frac{r}{\sqrt{1+r^2}} \ .$$

The imbedding fails for $|ka| > 1$ and is unique apart from the parameter k characterizing the duration of the critical cosmology. The radius of the horizon is given by

$$R = \int \frac{1}{a}\sqrt{1 - \frac{R^2k^2}{1-k^2a^2}}$$

and diverges. This tells that there are no horizons and therefore cosmological principle is realized. Infinite horizon radius could be seen as space-time correlate for quantum criticality implying long range correlations and allowing to realize cosmological principle. Therefore thermal realization of cosmological principle would be replaced with quantum realization in TGD framework predicting long range quantal correlations in all length scales. Obviously this realization is a in well-defined sense the diametrical opposite of the thermal realization. The dark matter hierarchy is expected to correspond to the microscopic realization of the cosmological principle generating the long range correlations.

Critical cosmology could describe the phase transition increasing Planck constant associated with a magnetic flux tube leading to its thickening. Magnetic flux would be conserved and the magnetic energy for the thicknened portion would be reduced via its partial transformation to radiation giving rise to ordinary and dark matter.

3.5 Fractal hierarchy of cosmologies within cosmologies

Many-sheeted space-time leads to a fractal hierarchy of cosmologies within cosmologies. In zero energy ontology the realization is in terms of causal diamonds within causal diamonds with causal diamond identified as intersection of future and past directed light-cones. One can say that everything can be created from vacuum. The temporal distance between the tips of CD is given as an integer multiple of CP_2 time in the most general case and boosts of CDs are allowed. The are also other moduli associated with CD and discretization of the moduli parameters is strong suggestive.

Critical cosmology corresponds to negative value of "pressure" so that it also gives rise to accelerating expansion. This suggests strongly that both the inflationary period and the accelerating expansion period which is much later than inflationary period correspond to critical cosmologies differing from each other by scaling. Continuous cosmic expansion is replaced with a sequence of discrete expansion phases in which the Planck constant assignable to a magnetic flux quantum increases and implies its expansion. This liberates magnetic energy as radiation so that a continual creation of matter takes place in various scales.

This fractal hierarchy is the TGD counterpart for the eternal inflation. This fractal hierarchy implies also that the TGD counterpart of inflationary period is just a scaled up invariant of critical cosmologies within critical cosmologies. Of course, also radiation and matter dominated phases as well as asymptotic string dominated cosmology are expected to be present and correspond to cosmic evolutions within given CD.

The multiverse of inflationary scenarios is replaced with the many-sheeted space-time (recall that various p-adic physics as correlates for cognition and the hierarchy of Planck constants mean quite a generalization so that a lot o new physics emerges) and one can say that the laws of physics are essentially same everywhere in the sense that the fundamental symmetries are the symmetries of the standard model everywhere.

3.6 Vacuum energy density as magnetic energy of magnetic flux tubes and accelerating expansion

TGD allows a more microscopic view about cosmology based on the vision that primordial period is dominated by cosmic strings which during cosmic evolution develop 4-D M^4 projection meaning that the thickness of the M^4 projection defining the thickness of the magnetic flux tube gradually increases [6]. The magnetic tension corresponds to negative pressure and can be seen as a microscopic cause of the accelerated expansion. Magnetic energy is in turn the counterpart for the vacuum energy assigned with the inflaton field. The gravitational Planck constant assignable to the flux tubes mediating gravitational interaction nowadays is gigantic and they are thus in macroscopic quantum phase. This explains the cosmological principle at quantum level.

The phase transitions inducing the boiling of the magnetic energy to ordinary matter are possible. What happens that the flux tube suffers a phase transition increasing its radius. This however reduces the magnetic energy so that part of magnetic energy must transform to ordinary matter. This would give rise to the formation of stars and galaxies. This process is the TGD counterpart for the re-heating transforming the potential energy of inflaton to radiation. The local expansion of the magnetic flux could be described in good approximation by critical cosmology since quantum criticality is in question.

One can of course ask whether inflationary cosmology could describe the transition period and critical cosmology could correspond only to the outcome. This does not look very attractive idea since the CP_2 projections of these cosmologies have dimension D=1 and D=2 respectively.

In TGD framework the fluctuations of the cosmic microwave background correspond to mass density gradients assignable to the magnetic flux tubes. An interesting question is whether the flux tubes could reveal themselves as a fractal network of linear structures in CMB. The prediction is that galaxies are like pearls in a necklace: smaller cosmic strings around long cosmic strings. The model discussed for the formation of stars and galaxies discussed in the previous section gives a more detailed view about this.

3.7 What is the counterpart of cosmological constant in TGD framework?

In TGD framework cosmological constant emerge when one asks what might be the GRT limit of TGD [7], [1]. Space-time surface decomposes into regions with both Minkowskian and Euclidian signature of the induced metric and Euclidian regions have interpretation as counterparts of generalized Feynman graphs. Also GRT limit must allow space-time regions with Euclidian signature of metric - in particular CP_2 itself - and this requires positive cosmological constant in this regions. The action principle is naturally Maxwell-Einstein action with cosmological constant which is vanishing in Minkowskian regions and very large in Euclidian regions of space-time. Both Reissner-Nordström metric and CP_2 are solutions of field equations with deformations of CP_2 representing the GRT counterparts of Feynman graphs. The average value of te cosmological constant is very small and of correct order of magnitude since only Euclidian regions contribute to the spatial average. This picture is consistent with the microscopic picture based on the identification of the density of magnetic energy as vacuum energy since Euclidian particle like regions are created as magnetic energy transforms to radiation.

3.8 Dark energy and cosmic consciousness

The hierarchy of Planck constants makes possible macroscopic quantum coherence in arbitrarily long scales. Macroscopic quantum coherence is essential for life and the notion of magnetic body is central in TGD inspired biology. For instance, the braiding of flux tubes making possible topological quantum computation like processes [2]. The findings of Peter Gariaev [2, 3, 5] provide support for the notion of magnetic body containing dark matter [1]. The notion of magnetic body also inspires science fictive ideas like remote replication of DNA [8] for which there is also some support and which could be essential for understanding water memory [4, 1].

The gravitational Planck constant $\hbar_{gr} = GM_1M_2/v_0$ (v_0 is dimensionless parameter in units for which $c = 1$ but has interpretation as velocity) assumed in the model of planetary system based on Bohr orbitology [5, 4] is assigned to the magnetic flux quanta mediating gravitational interaction between objects with masses M_1 and M_2 ($M_1 = M_2$ for self gravitation). For these values of Planck constant the quantum scales are gigantic. Even for gravitational mgnetic flux tubes connecting electron with Sun, the Compton length would be of the order of the radius of Sun. If there are ordinary particles at these flux tubes, their Compton length is enormous and their density is essentially constant.

The fractality of TGD Universe and of the magnetic flux tube hierarchy forces to ask whether intelligent consciousness could be possible in cosmic scales and be based on the Indra's net of the magnetic flux tubes. This cosmic nervous system would carry dark energy as magnetic energy with magnetic tension responsible for the negative "pressure" causing accelerated expansion. This Indra's web would act as super-intelligence taking the role of God by creating stars and galaxies by transforming magnetic energy to radiation and matter in phase transitions increasing the Planck constant and driving the evolution of this cosmic intelligence. In inflationary scenario inflaton field would have similar role. In zero energy ontology there is no deep reason preventing for the creation of entire sub-cosmologies from vacuum.

Books related to TGD

[1] P. Gariaev and M. Pitkänen. Model for the Findings about Hologram Generating Properties of DNA. In *Genes and Memes*. Onlinebook. http://tgdtheory.com/public_html/genememe/genememe.html#dnahologram, 2011.

[2] M. Pitkänen. DNA as Topological Quantum Computer. In *Genes and Memes*. Onlinebook. http://tgdtheory.com/public_html/genememe/genememe.html#dnatqc, 2006.

[3] M. Pitkänen. Does TGD Predict the Spectrum of Planck Constants? In *Towards M-Matrix*. Onlinebook. http://tgdtheory.com/public_html/tgdquant/tgdquant.html#Planck, 2006.

[4] M. Pitkänen. Quantum Astrophysics. In *Physics in Many-Sheeted Space-Time*. Onlinebook. http://tgdtheory.com/public_html/tgdclass/tgdclass.html#qastro, 2006.

[5] M. Pitkänen. TGD and Astrophysics. In *Physics in Many-Sheeted Space-Time*. Onlinebook. http://tgdtheory.com/public_html/tgdclass/tgdclass.html#astro, 2006.

[6] M. Pitkänen. TGD and Cosmology. In *Physics in Many-Sheeted Space-Time*. Onlinebook. http://tgdtheory.com/public_html/tgdclass/tgdclass.html#cosmo, 2006.

[7] M. Pitkänen. The Relationship Between TGD and GRT. In *Physics in Many-Sheeted Space-Time*. Onlinebook. http://tgdtheory.com/public_html/tgdclass/tgdclass.html#tgdgrt, 2006.

[8] M. Pitkänen and P. Gariaev. Quantum Model for Remote Replication. In *Genes and Memes*. Onlinebook. http://tgdtheory.com/public_html/genememe/genememe.html#remotereplication, 2011.

Articles about TGD

[1] M. Pitkänen. TGD inspired vision about entropic gravitation. http://tgdtheory.com/public_html/articles/egtgd.pdf, 2011.

Cosmology and Astro-Physics

[1] Cosmic inflation. http://en.wikipedia.org/wiki/Cosmic_inflation.

Biology

[1] L. Montagnier et al. DNA waves and water. http://arxiv.org/abs/1012.5166, 2010.

[2] P. Gariaev et al. *The DNA-wave biocomputer*, volume 10. CHAOS, 2001.

[3] P. P. Gariaev et al. The spectroscopy of bio-photons in non-local genetic regulation. *Journal of Non-Locality and Remote Mental Interactions*, (3), 2002.

[4] S. Ferris J.-L. Montagnier L. Montagnier, J. Aissa and C. Lavall'e. Electromagnetic Signals Are Produced by Aqueous Nanostructures Derived from Bacterial DNA Sequences. *Interdiscip. Sci. Comput. Life Sci.*, 2009.

[5] A.V. Tovmash P. P. Gariaev, G. G. Tertishni. Experimental investigation in vitro of holographic mapping and holographic transposition of DNA in conjuction with the information pool encircling DNA. *New Medical Tehcnologies*, 9:42–53, 2007.