About the TGD counterpart of the inflationary cosmology

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Abstract

Inflation theory as a proposal for the primordial cosmology is motivated by the problems of the standard cosmology. Multiverse is the basic problem caused by exponential expansion.

TGD counterpart for the inflation is based on the assumption of quantum coherence in arbitrarily long length scales and avoids the multiverse catastrophe. This would be due the presence of arbitrarily long string-like objects, which are 4-surfaces of $H = M^4 \times CP_2$ with 2-D M^4 projection. Quantum coherence is possible in string length scale. Cosmic strings are unstable against thickening to monopole flux tubes. The liberated energy transforms to ordinary particles or their variants with $h_{eff} = nh_0$ behaving like dark matter and located at the monopole flux tubes. These phases explain the missing baryonic mass whereas the energy of the cosmic strings explains the galactic dark matter. The thickening leads to the formation of galaxies and smaller astrophysical objects as flux tube tangles. The thickening process generates Einsteinian space-time with space-time surfaces having 4-D M^4 projection and generates radiation dominated cosmology.

Number theoretical approach predicts hierarchies of primary and secondary p-adic length scales and the dark variants of these hierarchies proportional to $h_{eff}/h_0 = n$ identifiable as dimension of extension of rationals determining p-adic length scales of ramified primes associated with the polynomials giving rise to the extension. The critical mass density can be understood in terms of the Hubble constant H_0 determined by the cosmological constant and identified as a secondary p-adic dark scale proportional to $h/h_0 = n_0$. The dark primary p-adic scale would correspond to the size scale of the neuron and the ordinary p-adic length scale to the p-adic length scale of the electron. The proposal is that the fluctuations of CMB background can be understood number-theoretically as induced by the fluctuations of n_0 and therefore of Planck constant h. This also suggests a solution of the problem posed by two different values of Hubble constants in terms of especially large local fluctuation in the value of h_{eff}.

Contents

1 Introduction

The question of Marko Manninen related to the inflation theory (see this) inspired the following considerations related to the TGD counterpart of the inflationary period assumed to precede the radiation dominated phase and to produce ordinary matter in the decay of inflaton fields. I have considered the TGD analog of inflation already 12 years ago [L1] [K6] and the recent discussion brings in the progress in the understanding occurred during these years.

Recall that inflation theory was motivated by several problems of the standard model of cosmology: the almost constancy of the temperature of the cosmic microwave background; the nearly flatness of 3-space implying in standard cosmology that the mass density is very nearly critical; and the empirical absence of magnetic monopoles predicted by GUTs. The proposal solving these problems was that the universe had critical mass density before the radiation dominated cosmology, which forced exponential expansion and that our observable Universe defined by the horizon radius corresponds to a single coherent region of 3-space.

The critical mass density was required by the model and exponential expansion implying approximate flatness. The almost constant microwave temperature would be due to the exponential decay of temperature gradients and diluted monopole density. The model also explained the temperature fluctuations as Gaussian fluctuations caused by the fluctuations of the mass density. The generation of matter from the decay of the energy density of vacuum assigned with the vacuum expectation values of inflaton fields was predicted to produce the ordinary matter. There was however also a very severe problem: the prediction of a multiverse: there would be an endless number of similar expanded coherence regions with different laws of physics.

A very brief summary of the recent view of the TGD variant of the inflation theory proposed earlier [L1] is in order before going into the details.

1. The TGD view is based on a new space-time concept: space-time surfaces are at the fundamental level identified as 4-D surfaces in $H = M^4 \times CP_2$. They have rich topologies and they are of finite size. The Eisteinian space-time of general relativity as a small metric deformation of empty Minkowski space M^4 is predicted at the long length scale limit as an effective description. TGD however predicts a rich spectrum of space-time topologies which mean deviation from the standard model in short scales and these have turned out to be essential not only for the understanding of primordial cosmology but also the formation of galaxies, stars and planets.

2. In TGD, the role of inflaton fields decaying to ordinary matter is taken by what I call cosmic strings, which are 3-D extremely thin string-like objects of form $X^2 \times Y^2 \subset M^4 \times CP_2$, have a huge energy density (string tension) and decay to monopole flux tubes and liberate ordinary matter and dark matter in the process. That cosmic strings and monopole flux tubes form a "gas" in $M^4 \times CP_2$ solves the flatness problem: M^4 is indeed flat!

   TGD also involves the number theoretic vision besides geometric vision: these visions are related by what I call $M^8 - H$ duality, see for instance [L6, L7] for the odyssey leading to its recent dramatically simplified form [L13]. The basic prediction is a hierarchy of Planck constants $h_{eff} = nh_0$ labelling phases of ordinary matter behaving like dark matter: these phases explain missing baryonic matter whereas galactic dark matter corresponds to dark energy as the energy of monopole flux tubes.

   Quantum coherence becomes possible in arbitrarily long scales and in cosmic scales gravitational quantum coherence replaces the assumption that the observed universe corresponds to an exponentially expanding coherence region and saves it from the multiverse. This solves the problem due to the constancy of the CMB background temperature.

3. In the TGD framework, cosmic strings thickened to monopole flux tubes are present in the later cosmology and would define the TGD counterpart of critical mass density in the inflationary cosmology but not at the level of space-time but in $M^4 \subset M^4 \times CP_2$. The monopole flux tubes are always closed: this solves the problem posed by the magnetic monopoles in GUTs. Monopole flux tubes also explain the stability of long range magnetic fields, which are a mystery in standard cosmology even at the level of planets such as Earth.

4. The fluctuations of CMB temperature would be due to the density fluctuations. In inflation theory they would correspond to the fluctuations of the inflaton field vacuum expectation values. In TGD, the density fluctuations would be associated with quantum criticality explaining the critical mass density ρ_{cr}. The fluctuations $\delta\rho_{cr}$ of the critical mass density for the monopole flux tubes would be due to the spectrum for the values of effective Planck constant h_{eff}: one would have $\delta T/T \propto \delta h_{eff}/h_{eff}$. This would give a direct connection between cosmology and quantum biology where the phases with large h_{eff} are in a fundamental role.

2 Some basic notions of TGD

2.1 Cosmic strings and monopole flux tubes

In the TGD Universe space-times are 4-D surfaces in $H = M^4 \times CP_2$.

1. Cosmic strings [K2, K6] are 3-D string like objects which have 2-D M^4 projection and do not have any counterpart in GRT. They are of the form $X^2 \times Y^2 \subset M^4 \times CP_2$, where X^2 is a string world sheet and Y^2 is a complex sub-manifold of CP_2, say geodesic sphere. They can be arbitrarily long and have length measured even in billions of light years. They are not possible in string models or in GUTs.

2. Cosmic string world sheets are unstable against the thickening of their 2-D M^4 projection making it 4-dimensional. This thickening creates what I call Einsteinian space-time. The thickening reduces the string tension and liberates energy as ordinary matter and the TGD counterpart of galactic dark matter. This decay process is the TGD counterpart of inflaton field decay.

   This process repeats itself as a similar process for monopole flux tubes but the liberated energy liberated decreases. The recent accelerating period of expansion could correspond to this kind of phases transition. The thickening *need not* involve exponential expansion of these space-time surfaces. This decay wold lead from the cosmic string dominated phase to a radiation dominated phase and generate Einsteinian space-time and cosmology.

3. The energy of the cosmic strings generates transversal $1/\rho$ gravitational field and cosmic strings orthogonal to galactic planes explain galactic dark matter yielding the flat velocity spectrum of stars in the galactic plane. No dark matter halo is needed as in ΛCDM model. Galactic dark matter as dark energy would not form a halo but a string-like structure. The prediction is that galaxies are formed as tangles of thickened cosmic strings along these very long cosmic strings. Zeldowich discovered these linear structures formed by galaxies decades ago [**?**] but they have been "forgotten".

2.2 $M^8 - H$ duality

Before proceeding, one must say something about $M^8 - H$ duality.

1. In the earlier versions of $M^8 - H$ duality [L2, L3, L4, L6, L7, L9], the integer n appearing in $h_{eff} = nh_0$ corresponds to a dimension of an algebraic extension of rationals assignable to a single octonion polynomial $P(o)$ with integer coefficients defined in the space of complexified octonions O_c. The polynomials would have as roots possibly complex mass shells in $M_c^4 \subset M_c^8$ and these would partially define the 3-D data of number theoretic holography in M^8.

2. It turns out that a correct spectrum of fluxtuations is predicted if one has $n = n_1 n_2$ where n_i are identical or nearly identical. One can consider several variants for the composition of n

to a product of integers. For instance, for the polynomimals defined as functional composites of polynomials P_i have dimension of extension which is product $\prod_i n_i$ of the dimensions n_i for the polynomials P_i. The decomposition of n to product could physically correspond to various interactions.

The factors in the product could also correspond to M^4 and CP_2 degrees of freedom and this option suggested by the recent view of $M^8 - H$ duality [L13]. As a matter of fact, I proposed this kind of decomposition in the beginning of $M^8 - H$ adventure but gave it up.

3. The most recent formulation of $M^8 - H$ duality [L13] is dramatically simpler than the earlier ones. Complexified octonsions $O_c = M_c^8$ is replaced with octonions O allowing naturally a Minkowskian number theoretic norm $Re(o^2)$ making O effectively M^8. The holography = holomorphy principle at the level of H together with $M^8 - H$ duality fixes the number theoretic holography at the level of M^8 (normal space of 4-surface is associative and contains 2-D commutative subspace there is no need to define number theoretic holography using polynomials $P(o)$ in M_c^8. It seems that all nice features of the earlier proposal apply also to this proposal.

   The vanishing of 2 holomorphic functions of 4 generalized complex coordinates of H defines 4-D space-time surfaces in H [L8, L12]. These holomorphic functions form naturally a hierarchy of pairs of polynomials P_i, $i = 1, 2$, and one can assign toP_i an extension of rationals with dimension n_i, $i = 1, 2$. Could one identify $h = h_{eff}/h_0 = n$ as the product $n = n_1 n_2$? Note that n_1 and n_2 can also factorize to primes.

   Number theoretic vision forces the increase of algebraic complexity meaning the increase of h_{eff} during cosmic evolution. $h_{eff} = h_0$ would be the simplest option in the primordial phase, where things are as simple as possible.

2.3 Hierarchies of p-adic length scales and effective Planck constants

The number theoretic vision of TGD implies hierarchies of p-adic length scales labelled by powers of p-adic primes p. Each p-adic hierarchy is accompanied by a hierarchy of dark scales and a hierarchy of phases behaving like dark matter. p-Adic length scale hypothesis, motivated by p-adic mass calculations [K3, K1], states that primes near some powers of 2 are physically preferred p-adic primes strengthens this hypothesis.

1. For a given prime p there exists entire hierarchy of p-adic length scales $L_{p,n} = p^{(n-1)/2)} L_p$, where one has $L_p = sqrtpR$, where R equals to the radius of CP_2 apart from a numerical constant.

2. The hierarchy of Planck constants $h_eff = nh_0$, where h_0 is the minimal value of effective Planck constant defines a hierarchy of phases of ordinary matter behaving like dark matter. This hierarchy solves the missing baryon problem whereas the energy of cosmic strings explains the galactic dark matter. The dark scales are given by $L_{p,n}^{dark} = \hbar_{eff} L_{p,n}$.

3. These two hierarchies are not independent since a given extension of rationals determining $h_{eff}/h_0 = n$ as its dimension defines also a set of p-adic primes p as a ramified prime for a polynomial defining the extension. The largest p-adic prime p_{max} is in a special physical role. The phase transitions changing the extension of rationals and the value of h_{eff} are possible and change the length scale of the monopole flux tube. Reconnections of the flux tubes define their topological dynamics and are in a central role in TGD inspired quantum chemistry and explain the basic mysteries of biocatalysis. Simple calculations show that p_{max} can be exponentially larger than n_0 [L11].

4. The ramified primes are bounded if one assumes that the coefficients of polynomials P are smaller than their degrees and imply that the number of polynomials with a smaller degree is finite for a given degree: this forces a number theoretic evolution in a very strong sense.

2.4 Zero energy ontology

In the TGD framework, zero energy ontology (ZEO) [L5] [K8] is the central element of quantum measurement theory and provides additional insights to the situation.

1. ZEO ontology involves as a basic concept the notion of causal diamond (CD) [L10] [L13] as an interaction of future and past directed light-cones. CD is characterized by its size identifiable as the distance between its tips. The sizes of CDs form scaling hierarchies labelled by $h_{eff}/h_0 = n$ and p-adic length scales L_p. At least L_p, $L_{p,2} = \sqrt{p}L_p$, and the dark scales nL_p and $nL_{p,2}$ are fundamenal scales. The p-adic primes p correspond to the ramified primes assignable to the polynomials defining the extension and p_{max} is in a preferred position.

2. The interpretation of CD is as the perceptive field of a conscious entity: CD could correspond to the part of the Universe perceivable to corresponding conscious entityt and CD size would serve as the analog for horizon radius. The size of CD would naturally define the scale of quantum coherence and would increase during the cosmic evolution as n increases. It could be however arbitrarily long already in primordial phase if rational polynomials are allowed.

3 The TGD view of primordial cosmology

I have already earlier consider primordial cosmology in the TGD framework [L1] [K6].

3.1 Primordial cosmology and the almost constant temperature of the CMB

Primordial cosmology preceding the radiation dominated phase corresponds in the TGD framework to a "gas" like phase formed by a network of cosmic strings, which could be arbitrarily long and are always closed. Reconnection is the basic topological reaction for them. This phase has no counterpart in Einstein's theory.

A natural assumption is that there is a quantum coherence along the string. This means a hierarchies of quantum coherence scales assignable to cosmic strings and monopole flux tubes, which in the number theoretic vision of TGD would correspond to p-adic length scales and to a hierarchy of dark scales assignable to the h_{eff} a hierarchy of phases behaving like dark matter.

1. The p-adic length scales L_p could characterize the thickness of the monopole flux tubes and, as it turns out, $L_{p,2}$ could characterize the lengths of strings and flux tubes.

2. The dark length scales $nL_{p,n}$, $n = h_{eff}/h_0$ would be associated with the dark variants of the strings and monopole flux tubes. p would correspond to a ramified prime for a polynomial P defining an extension of rationals with dimension n and there is a large number of polynomials of this kind. The maximal p-adic prime for given P and n is in a physical special role and defines the maximal thickness and length of the flux tube in this case.

What about the p-adic length scales associated with the primordial phase? Assume the holography=holomorphy vision [L12, L14] so that a pair of polynomials defines the space-time surface and these polynomials define extension rationals assignable to M^4 and CP_2 degrees of freedom.

One can consider two options.

1. The simplest option is that cosmic strings correspond to $p = 1$ for which the flux tube is infinitely thin and the extension of rationals is trivial ($n = 0$). This would mean that flux tubes would have the same minimal length defined by CP_2 radius R. Primordial quantum coherence would be possible only in CP_2 scale.

2. There is also a more complex option.

   (a) The transversal scale of the cosmic string corresponds to CP_2 length scale R and is minimal. The CP_2 projection Y^2 as a complex surface can however have several sizes. One could however argue that they do not correspond to p-adic length scales and $p = 1$ corresponding to linear polynomials of CP_2 coordinates allowing only a homologically non-trivial geodesic sphere is possible.

(b) What about M^4 degrees of freedom? Could one allow the reduction of the polynomials of 4 four complex (or hypercomplex) variables to non-irreducible polynomials when 3 complex variables are fixed to rational values (say put equal to zero). These would also allow rational roots. If all roots are rational, $n = 0$ is true. Does it make sense to identify the ramified primes as prime factors of the determinant identified as the square of the product of root differences ($b^2 - 4ac$ for a second order polynomial). If so, one could have p-adic primes $p \geq 2$ also in the primordial phase. Strings could have arbitrary long lengths also in this phase but no dark phases would be present.

For this option a primordial quantum coherence would be possible in arbitrarily long p-adic length scales. Only the dark phases would emerge during evolution. This option conforms with the recent view of TGD.

In ZEO causal diamond (CD=cd$\times CP_2$) defines the perceptive field of conscious entity. cd is analogous to a empty cosmology as a big bang followed by big crunch.

1. What determines the size of the CD in the recent cosmology? The ratio of CP_2 radius to Planck length is in the range $10^3 - 10^4$ from p-adic mass calculations. Could the recent mean value $h_{eff} = h = n_0 h_0$ correspond to CP_2 length scale R perhaps identifiable as the length scale of M^4 projection of monopole flux tube? The value of n_0 is in the range $10^7 - 10^8$.

2. The scale defined as the geometric mean of Planck length and the length scale L defined by cosmological constant Λ defines the size scale of a large neuron around $L_m \sim 10^{-4}$ m. One can think that $_m$ is for "meso": L_m is the fundamental biological scale determined as a geometric mean of two scales: Planck length for microcosmos and Hubble radius for macroscosmos. The basic scale of biological systems would correspond to the geometric mean of horizons scale and Planck scale. The geometric mean property implies that L_m and L can be expressed as $L_n = xL_0$ and $L = x^2 L_0$ which strongly suggests that these scales are primary and secondary length scales for some prime p.

3. In the twistor lift of TGD [K7, K5, ?, ?], the cosmological constant Λ appears as the coefficient of the 4-volume term in the dimensionally reduced Kähler action determining as its preferred extemals 6-D twistor space as 6-surface in the product of 6-D twistor spaces of M^4 and CP_2 having two-sphere S^2 as a fiber and the space-time surface $X^4 \subset H$ as the base space. The only spaces having a twistor space with Kähler structure are M^4 and CP_2 [A1] so that TGD is unique.

4. Twistor lift suggests that $L_m = xL_P$, $x \equiv L_m/L_P = \sqrt{L/l_P} \sim 10^{31}/1.65$, defines the maximal thickness of a typical monopole flux tube in the recent cosmos. The scale $x^2 L_P$ in turn could define the scaling factor giving the maximal length L of the cosmic string determining the size scale of the CD. The natural identification would be as Hubble length $\hbar/H_0$, which is determined by the cosmological constant Λ. There are two scales: do they correspond to scales assignable to ordinary matter and dark matter at the highest possible level of the magnetic body of the system?

Could one understand the value of x number theoretically? Certainly it cannot correspond to the ratio $n_0 = h/h_0 \in [10^7 - 10^8]$. Much larger values are required.

1. Number theoretical approach predicts besides dark scales also p-adic length scales. The primary p-adic length scale L_p and secondary p-adic length $L_{2,p} = \sqrt{p} L_p$ and possibly also higher p-adic length scales forming a hierarchy in powers of $\sqrt{p}$. Could x and x^2 correspond to the dark primary length scale $nL_p \propto n\sqrt{p}R$ and to the dark secondary p-adic length scale $nL_{p,2} = npR$? p would be a ramified prime determined by the extensions of rationals determined by the value of h_{eff}.

   There are two options. In the recent universe either a) L_p or b) nL_p could correspond to a p-adic length scale assignable to neuron. For option a) nL_p would correspond to a scale in the range $10^3 - 10^4$ m. For option b) L_p would correspond to a length scale in the range $10^{-12} - 10^{-11}$ m (electron Compton length is 2.4×10^{-12} m).

   Secondary p-adic length scale $L_{2,p}$ would correspond to the horizon radius $\hbar/H_0$ and $nL_{2,p}$ to the radius of dark horizon assignable to the field body of cosmos perceivable to us.

2. During the primordial phase, the size of CD could correspond to Planck length or to CP_2 radius R. One could have $l_P = R$ for $h_{eff} = h_0$. In the recent situation one would $h = n_0 h_0$ and $R^2_{eff} = n_0 R^2 = n_0 \sqrt{G}$, perhaps identifiable as the scale of the M^4 projection of cosmic string (see below). n_0 would correspond to the dimension of extension of rationals and the p-adic prime p to a ramified prime of extension. There would be at least two CD sizes defined by $L_m = x L_P$ and $L = x^2 L_P$, where one has $x = \sqrt{p/2}$ and p is a ramified prime of the extension of rationals considered.

3.2 Do quantum fluctuations replace the thermal fluctuations of inflation theory?

If long length scale quantum coherence is possible in the length scale of cosmic strings, one ends up with the following questions.

1. Does gravitational quantum coherence due to long cosmic strings explain the almost constant value of the CMB temperature? One has $\rho \propto T^4$, which gives $\delta T/T \propto 4\delta\rho/\rho$.

   One can imagine two options.

   (a) If arbitrarily long cosmic strings are possible in the primordial phase (rational polynomials are allowed), quantum coherence could be present in all scales already in the primordial phase with $h_{eff} = h_0$. This option conforms with the original proposal.

   (b) If the lengths of cosmic strings are bounded in the primordial phase so that they are proportional too h_{eff}, long cosmic strings must be created later by reconnection in phase transitions increasing the value of h_{eff} allowing larger p-adic primes defining p-adic lengths scales. These phase transitions would also increase the length of cosmic strings.

2. In the inflation model, the fluctuations of CMB temperature are due to the density fluctuations $\delta\rho/\rho$. Could these density fluctuations be reduced to the fluctuations of the density in the phase formed by the cosmic strings in the primordial phase and later in the phase formed by the monopole flux tubes (magnetic bodies) characterized by the value of h_{eff}?

3. Inflationary cosmology is critical in the sense that mass density $\rho_{cr} = 3H_0^2/8\pi G$, where H_0 is the Hubble constant, is critical. In the TGD framework, this formula holds true at the level of future light-cone $M^4_+ \subset M^4 \subset H = M^4 \times CP_2$ representing empty standard cosmology rather than at space-time level as in inflation theory. Therefore exponential expansion is not needed for this formula. The quantum criticality would naturally apply to the phase formed by ordinary particles at monopole flux tubes characterized by the values h_{eff}.

4. Quantum criticality means a spectrum of the values of $h_{eff} = nh_0$. How do the fluctuations of h_{eff} imply the density fluctuations?

   The dimension of G is $[L^2]/[h]$. In TGD the only dimensional parameter is CP_2 length scale R and this suggests the formula $G = R^2/\hbar$, which generalizes to the formula $G = R^2/\hbar_{eff}$. One must have $\hbar \sim (10^7 - 10^8)\hbar_0$ to explain CP_2 radius fixed by electron mass from p-adic mass calculations.

   Again one can consider two options.

   (a) R is a fundamental constant and the value of $G_{eff} = R^2/h_{eff}$ varies and is different in the dark phases and decreases with h_{eff}. This looks strange but since we cannot yet observe dark matter, one cannot exclude this option. For this option one would have for the dark matter $\rho_{cr} = 3H_0^2/4\pi G_{eff} = 3\hbar_{eff} H_0^2/4\pi R^2$.

   (b) $G = R^2/\hbar_0$ is a fundamental constant and the effective radius squared $R^2_{eff} = \hbar_{eff} R^2/\hbar_0$ of CP_2 varies. It could geometrically correspond to the size of the M^4 projection of the cosmic string, or more precisely the thickening of $Y^2 \subset CP_2$. CP_2 scale would correspond to the Planck scale. For this option one would have $\rho = 3\hbar_0 H_0^2/4\pi R^2_{eff} = 3\hbar_{eff}/4\pi L_p^2$.

For both options the density of dark matter would increase with $\hbar_{eff}$.

Consider now what quantum criticality predicts.

1. Criticality means that one has $\rho = \rho_{cr} = 3H_0^2/8\pi G$ so that the fluctuations would correspond to fluctuations of Hubble constant: $\delta\rho/\rho = 2\Delta H_0/H_0$. Quantum criticality means that the quantum state is a superposition of states with different values of h_{eff}. This means fluctuations and long range correlations since quantum coherence scales are typically proportional to h_{eff} and even h_{eff}^2 as in atomic physics.

   This implies that the thermal fluctuations are induced by the fluctuations of $\hbar_{eff}/h_0 = n$ and by the polynomial defining the extension of rationals with dimension n.

2. What one wants is that $\delta H_0/H_0 \sim \delta n/n$. How to achieve this? Suppose that $\hbar/H_0$ corresponds to a dark secondary p-adic length scale for extension with $h_{eff} = n_0 h_0 = h$. One has therefore $1/H_0 = kn_0 L_{p,2}$, where k is numerical constant, and $L_{p,2} = \sqrt{p}L_p$ is secondary p-adic scale assignable to the extension. $n_0 L_p$ must correspond to $L_m \sim 10^{-5}$ so that one would have $L_p \in [10^{-12}, 10^{-11}]$, the p-adic length scale $L_{M_{127}} \simeq \sqrt{5}L_c = 5.4 \times 10^{-12}$ m is highly suggestive. This would correspnd to $n_0 \simeq 1.85 \times 10^7$.

   (a) Suppose that $p = p_{max}(P_{|n})$, that is the largest ramified prime assignable to a polynomial P defining the extension of rationals with dimension n. Several extensions can have dimension n exist and several polynomials P could in principle define an extension with a given value of n and the same value of $p_{max} = p$.

   (b) For an extension with a given value of n, one can allow fluctuations defined by polynomials with different values of p_{max}. This gives a rough estimate $\delta H_0/H_0 = -(\delta n/n - dL_{p_{max}}/L_{p_{max}})$. The term $dL_{p_{max}}/L_{p_{max}} = \delta p_{max}/p_{max}$ is very small for large p-adic primes, and one would have $\delta H_0/H_0 \sim -\delta n/n$ giving $\delta H_0/H_0 \sim 1/n$ for $|\delta n| = 1$.

   $$\frac{\delta T}{T} = \frac{1}{2}\frac{\delta\rho_{cr}}{\rho_{cr}} = 2\frac{\delta H_0}{H_0} = -2\frac{\delta n}{n} \quad .$$

   (c) The temperature fluctuations of CMB would reveal the fluctuations of $n = \hbar_{eff}/h_0$ in turn inducing fluctuations of padic length scale $L_{p_{max},2}$ defining H_0.

The fluctuations of CMB would be a number theoretic phenomenon. Does this proposal conform with the observations?

1. Density fluctuations are in the range $\delta T/T \in [10^{-4}, 10^{-5}]$. The nominal value of $\delta T/T$ is $10^{-4}/3$ (see this). This corresponds to $\delta\rho_{cr}/\rho_{cr} = 4\delta T/T = 1.3 \times 10^{-4}$.

2. If the fluctuation corresponds to a single extension of rationals, or more generally, n is not a product of two or more statistically independent factors, one has $|\delta n| \geq 1$ and the $|\delta T|/T \sim (1/2)|\delta n|/n$. If one uses the estimate $n = R^2/G \in [10^7 - 10^8]$, one obtains $|\delta T|/T = (1/2)\sum_k p(|\delta|n = k)k/n$, which in the first approximation gives $|\delta T/T| = p(1)x/2$, $x \in [10^{-7}, 10^{-8}]$. The estimate is too small.

3. If one assumes that the decomposition $h_{eff}/h_0 = n_1 n_2$, where n_i are assumed to be statistically independent, one obtains $|\delta h_{eff}|/h_{eff} = |\delta n_1|/n_1 + |\delta n_2|/n_2$. If only $|\delta n_1| = 1$ and $|\delta n_2| = 1$ contribute significantly, and one has $|\delta|T/T = p(1)/n_1 + p(2)/n_2]/2$. Assuming $n_1 = n_2 \sim \sqrt{n} \in [10^{3.5}, 10^4]$, and $p_1 = p_2 = P$ one has very naive estimate $2P/\sqrt{n}$, $n \in [10^{-3.5}, 10^{-4}]$. The order of magnitude is correct.

4. The justification for the decomposition comes from the holography=holomorphy hypothesis, which implies that the two polynomials defining the space-time surface as a complex surface in generalized sense gives rise to two extensions of rationals with dimensions n_1 and n_2. These extensions can be assigned to M^4 degrees of freedom (string world sheets X^2) and to CP_2 degrees of freedom (partonic 2-surfaces Y^2). One can also consider the possibility that internal consistency requires the extensions to have the same dimension $n_1 = n_2$.

For the cold spot of CMB (see this), the temperature fluctuation of CMB is 70 μK and 4 times higher than on the average . Could one understand this number theoretically? For instance, could this could be due to $n_1 \rightarrow 8n_1$ and $n_2 = n_1 \rightarrow n_1/8$ in $n \rightarrow n_1 n_2 \sim n_1^2$ giving for $\delta n_1 = deltan_2 = 1$ the outcome $\delta n/n = 1/(8n_1) + 8/n_1 \simeq 8/n_1$ so that the fluctuation is 4 times larger.

3.3 About the problem of two Hubble constants

The usual formulation of the problem of two Hubble constants is that the value of the Hubble constant seems to be increasing with time. There is no convincing explanation for this. But is this the correct way to formulate the problem? In the TGD framework one can start from the following ideas discussed already earlier [K4].

1. Would it be better to say that the measurements in short scales give slightly larger results for H_0 than those in long scales? Scale does not appear as a fundamental notion neither in general relativity nor in the standard model. The notion of fractal relies on the notion but has not found the way to fundamental physics. Suppose that the notion of scale is accepted: could one say that Hubble constant does not change with time but is length scale dependent. The number theoretic vision of TGD brings brings in two length scale hierarchies: p-adic length scales L_p and dark length scale hierarchies $L_p(dark) = nL_p$, where one has $h_{eff} = nh_0$ of effective Planck constants with n defining the dimension of an extension of rationals. These hierarchies are closely related since p corresponds to a ramified prime (most naturally the largest one) for a polynomial defining an extension with dimension n.

2. I have already earlier considered the possibility that the measurements in our local neighborhood (short scales) give rise to a slightly larger Hubble constant? Is our galactic environment somehow special?

Consider first the length scale hierarchies.

1. The geometric view of TGD replaces Einsteinian space-times with 4-surfaces in $H = M^4 \times CP_2$. Space-time decomposes to space-time sheets and closed monopole flux tubes connecting distant regions and radiation arrives along these. The radiation would arrive from distant regions along long closed monopole flux tubes, whose length scale is L_H. They have thickness d and length L_H. d is the geometric mean $d = sqrt(l_P L_H)$ of Planck length L_P and length L_H. d is of about 10^{-4} meters and size scale of a large neuron. It is somewhat surprising that biology and cosmology seem to meet each other.

2. The number theoretic view of TGD is dual to the geometric view and predicts a hierarchy of primary p-adic length scales $L_p \propto \sqrt{p}$ and secondary p-adic length scales $L_{2,p} = \sqrt{p} L_p$. p-Adic length scale hypothesis states that p-adic length scales L_p correspond to primes near the power of 2: $p \simeq 2^k$. p-adic primes p correspond to so-called ramified primes for a polynomial defining some extension of rationals via its roots.

   One can also identify dark p-adic length scales

   $$L_p(dark) = nL_p \ ,$$

   where $n = h_{eff}/h_0$ corresponds to a dimension of extension of rationals serving as a measure for evolutionary level. h_{eff} labels the phases of ordinary matter behaving like dark matter explain the missing baryonic matter (galactic dark matter corresponds to the dark energy assignable to monopole flux tubes).

3. p-Adic length scales would characterize the size scales of the space-time sheets. The Hubble constant H_0 has dimensions of the inverse of length so that the inverse of the Hubble constant $L_H \propto 1/H_0$ characterizes the size of the horizon as a cosmic scale. One can define entire hierarchy of analogs of L_H assignable to space-time sheets of various sizes but this does not solve the problem since one has $H_0 \propto 1/L_p$ and varies very fast with the p-adic scale coming as a power of 2 if p-adic length scale hypothesis is assumed. Something else is involved.

One can also try to understand also the possible local variation of H_0 by starting from the TGD analog of inflation theory. In inflation theory temperature fluctuations of CMB are essential.

1. The average value of h_{eff} is $\langle h_{eff} \rangle = h$ but there are fluctuations of h_{eff} and quantum biology relies on very large but very rare fluctuations of h_{eff}. Fluctuations are local and one has $\langle L_p(dark) \rangle = \langle h_{eff}/h_0 \rangle L_p$. This average value can vary. In particular, this is the case for the p-adic length scale $L_{p,2}$ ($L_{p,2}(dark) = nL_{2,p}$), which defines the Hubble length L_H and H_0 for the first (second) option.

2. Critical mass density is given by $3H_0^2/8\pi G$. The critical mass density is slightly larger in the local environment or in short scales. As already found, for the first option the fluctuations of the critical mass density are proportional to $\delta n/n$ and for the second option to $-\delta n/n$. For the first (second) option the experimentally determined Hubble constant increases when n increases (decreases). The typical fluctuation would be $\delta h_{eff}/h \sim 10^{-5}$. What is remarkable is that it is correctly predicted if the integer n decomposes to a product $n_1 = n_2$ of nearly identical integers.

   For the first option, the fluctuation $\delta h_{eff}/h_{eff} = \delta n/n$ in our local environment would be positive and considerably larger than on the average, of order 10^{-2} rather than 10^{-5}. h_{eff} measures the number theoretic evolutionary level of the system, which suggests that the larger value of $\langle h_{eff} \rangle$ could reflect the higher evolutionary level of our local environment. For the second option the variation would correspond to $\delta n/n \leq 0$ implying lower level of evolution and does not look flattering from the human perspective. Does this allow us to say that this option is implausible?

   The fluctuation of h_{eff} around h would mean that the quantum mechanical energy scales of various systems determined by $\langle h_{eff} \rangle = h$ vary slightly in cosmological scales. Could the reduction of the energy scales due to smaller value of h_{eff} for systems at very long distance be distinguished from the reduction caused by the redshift. Since the transition energies depend on powers of Planck constant in a state dependent manner, the redshifts for the same cosmic distance would be apparently different. Could this be tested? Could the variation of h_{eff} be visible in the transition energies associated with the cold spot.

3. The large fluctuation in the local neighbourhood also implies a large fluctuation of the temperature of the cosmic microwave background: one should have $\Delta T/T \simeq \delta n/n \simeq \delta H_0/H_0$. Could one test this proposal?

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