The anomalies of cosmic microwave background from the TGD point of view

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Abstract

I have not previously systematically considered the CMB anomalies from the point of view of TGD. Cosmological Principle (CP) makes strong predictions. Inflationary cosmology explains the approximate constancy of the CMB temperature and predicts a scaling invariant spectrum for density perturbations: this predicts the angular dependence of the CMB temperature fluctuations. This prediction is however plagued by small anomalies. The CMB dipole is due to the motions of the solar system with respect to CMB. There is also a "matter" anomaly for galaxies and clusters in the scale of megaparsecs. Also there is also recent evidence for the so-called quasar anomaly. There is also evidence for dark flow in even longer scales larger than the horizon size.

The Axis of Evil anomaly is in sharp conflict with CP. The quadrupole coefficients are unexpectedly small and the directions assignable to the octupole and quadrupole coefficients are aligned and parallel to the and parallel to ecliptic which means a strong violation of CP. Besides this there are fluctuation anomalies: in particular, hemispherical asymmetry for the fluctuation strengths.

In this article a TGD based view of CMB is described. In TGD, Cosmological Principle fails at the level of space-time surfaces but is replaced with Poincare invariance at the level of $H = M^4 \times CP_2$: space-time sheets are like moving particles with each having its own CMB. The holography= holomorphy principle generalizes the scaling invariance to holomorphy of analytic functions of hypercomplex and 3 complex coordinates of H so that one has a generalization of conformal invariance to 4 dimensions. The quantum coherence possible in arbitrarily long scales and assigned to gravitational field bodies allows us to get rid of exponential expansion.This has also implications for the understanding of CMB. This picture leads to models of various CMB anomalies.

1 Introduction

I have not previously systematically considered the CMB anomalies from the point of view of TGD. It is good to start with a brief summary of TGD inspired cosmology.

1.1 The new cosmology and astrophysics predicted by TGD

The TGD based cosmology is many-sheeted and fractal like Russian doll cosmology [L10, L6, L7, L14, L16] .

1. Primordial cosmology is dominated by cosmic strings, unstable against thickening to monopole flux tubes. Flux tubes are characterized by thickness and length [L2]. The scale defined by the cosmological constant emerging naturally in twistor lift of TGD [K1] corresponds to the p-adic length assignable to the length of the cosmic string. The flux tube thickness corresponding to the cosmological constant for standard cosmology is estimated to be about 10^{-4} meters. Also thinner and thicker flux tubes are possible and one cannot exclude space-time regions, which are small deformations of pieces of M^4 with a non-vanishing cosmological constant. Long cosmic strings explain galactic dark matter as energy of a cosmic string or a bundle of them transversal to the galactic plane.

2. Instead of gravitational condensation, the formation mechanism for the galaxies and stars in the TGD Universe is the thickening of the cosmic string leading to a liberation of its energy and the formation of flux tube tangles. This process would have been initiated by the topologically unavoidable collisions of cosmic strings.

   This mechanism is analogous to inflation [L10, L6, L7, L14, L16] but quantum coherence in astrophysical scales due the arbitrarily large values of gravitational and electric Planck constants [L3, L4] makes exponential expansion un-necessary.

3. TGD also allows to consider a radically new view of the Sun itself [L12] based on the TGD based generalization of the standard model predicting a hierarchy of fractally scaled variants of the standard model [L15]. The surface layers in which a phase transition transforming M_{89} hadrons to ordinary hadrons would produce solar wind and solar energy. There would be the analog of metabolic energy feed of M_{89} hadrons from the galactic nucleus to the surface of the Sun. Interestingly, the spin axis of the galactic blackhole points towards the Earth.

   This view challenges also the reality of the standard view of cosmological nucleosynthesis eventually leading to a plasma of protons, neutrons and helium ions, which would have cooled down to a temperature making atoms possible and led to the formation of stars by gravitational condensation condensing to form galaxies.

4. It is also necessary to reconsider the view of the cosmic microwave background (CMB) [L10]. The cosmic history before the formation of the first stars could have been very different from the narrative of the standard cosmology. Instead of plasma of elementary particles, the gas of long cosmic strings in M^4 could have dominated and their collisions could have generated ordinary matter. CMB would have emerged as the first stars were formed [L17].

1.2 The replacement of Cosmological Principle (CP) with Poincare invariance and CP breaking of CMB

In the TGD framework, Cosmological Principle (briefly CP) at the space-time level is given up and extended to Poincare invariance at the level of the embedding space $H = M^4 \times CP_2$. This requires the replacement of the space-time of general relativity with the many-sheeted space-time in which space-time consists of 4-surfaces analogous to Bohr orbits of a 3-D particles. This implies a breaking of Cosmological Principle (CP) (This CP breaking has of course nothing to do with the CP violation of particle physics).Could the notion of the many-sheeted space-time, which violates the standard form of CP, provide an answer to various questions raised by the CMB anomalies?

1. CMB photons as analogs of Bohr orbits carry information about where they came from and also from what they experienced during its travel. What this means at fundamental geometric and quantum level can be understood concretely in ZEO. CMB is parametrized by its temperature T_{CMB}, whose dependence on direction angles $\Omega = (\theta, \phi)$ carries information about the history of the CMB photons. The angle dependence is parametrized by the multipole coefficients C_l for $T_{CMB}(\Omega)$.

2. The finite sized of Bohr orbits define quantum coherence regions. In principle, each space-time sheet has its own CMB defining the rest system.This means spectrum of T_{CMB} depending on the state of motion the Bohr orbit and also the moment when the CMB was generated. This give drise to additional effects analogous to the kinematic dipole and could explain the "matter" dipole and recently observed quasar dipole approximately orthogonal to the matter dipole and CMB dipole.

   The finite size of the space-time sheets could relate to the spatial fluctuations of T_{CMB} and also to the loss of angular correlations for angle separations larger than 60 degrees: for too large angular separations the CMB photons would come from disjoint space-time sheets.

3. In the TGD framework, M^4 light-cone proper time a corresponds to the scale parameter R of the Robertson-Walker metric. An attractive idea is that the spatial fluctuations of T_{CMB} correspond to the fluctuations for the value a_{CMB} of the light-cone proper time for the initiation of the transition producing CMB.

   The hemispherical asymmetry could be understood in terms of a phase transition propagating in the direction of asymmetry with velocity much larger than light velocity. If an external signal initiates the transition, this is indeed possible. The initiating signal could originate from a space-time sheet with size larger than the horizon size.

4. Could the existence of very long cosmic strings/flux tubes explain the coherent mass flows in cosmic scales? These flows could correspond to a free motion in direction parallel to the cosmic strings: this prediction distinguishes TGD from ΛCDM.These flows could relate to the observed dark flow, matter dipole and quasar dipole.

5. There are several explanations for the spatial fluctuations of T_{CMB}. They could be due to the Doppler effect caused by the motion of the solar system or by motion of the space-time sheets with their own CMB. They could be also due to the density fluctuations and they could be induced by the fluctuations of the time a_{CMB}. In TGD a_{CMB} is not necessarily associated with recombination leading to the formation of neutral atoms and decoupling of the CMB. It is also possible signals from distant stars propagate along monopole flux tubes and in this make them visible before the time of recombination.

1.3 Scale invariance of the fluctuation spectrum for the CMB temperature

The scale invariance of the fluctuation spectrum of CMB temperature assumed to be determined by the spectrum of primordial density perturbations is a rather successful basic prediction of the inflation theory.

1. In inflation theory, the conformal invariance reflects itself as the scale invariance of the spectrum of primordial density perturbations near the Big Bang. The amplitude for the fluctuations as a function of the scale is nearly flat: the amplitude $P(k)$ as the function of the wave vector k characterizing the scale is nearly constant.

2. Density perturbations give rise to temperature perturbations and the scale invariance should manifest itself in the angle dependence of $T_{CMB}(\Omega)$. This predicts a specific pattern in the angular power spectrum of the CMB temperature anisotropies. The multipole coefficients C_l show a characteristic behavior, including a prominent "peak" region at intermediate multipole moments l followed by a decay. This pattern is a direct result of the near-scale-invariant primordial fluctuations being stretched to different angular sizes in the sky.

3. More precisely, the Fourier expansion of the temperature perturbation is given by $\Delta T(x) = \int d^3kexp(ik\cdot x)\Delta T(k)$, where $T(k) \simeq \Delta T_0$ is approximately constant by approximate scale invariance. In coordinates in which $k\cdot x = kcos(\theta)$, this gives $\Delta T(x) = F(cos(\theta) \times \Delta T_0$, $F(cos(\theta) = \int exp(ik\cdot cos(\theta))k^2dk$.

   The partial waves assignable to $\Delta T(x)$ are proportional to $C_{l,m} = \int Y^l_m(\Omega)d\Omega F(cos(\theta))d\Omega$ and vanish for $m \neq 0$. This predicts a characteristic dependence on l $(m = 0)$.

The challenge is to translate this picture or its generalization to the framework of TGD.

1. This requires zero energy ontology (ZEO) in which causal diamonds $CD = cd \times CP_2 \subset H = M^4 \times CP_2$ as perceptive fields of conscious entities. cd as an intersection of future and past directed light-cones is analogous to a big bang followed by a big crunch. CDs define Russian doll cosmology. The primordial fluctuations correspond to the deformations of space-time surfaces near the boundary of cd.

   An essential element is the slight classical non-determinism of classical field equations, which actually forces ZEO. The 3-surfaces as particles must be replaced with their Bohr orbits and it becomes possible to talk about the history of a CMB photon, which is actually done also in the standard description.

2. Also holography= holomorphy vision (H-H) is required. It allows us to construct exact solutions of classical field equations as roots of analytic function pairs $f = (f_1, f_2)$ of functions analytic with respect to the hypercomplex coordinate of M^4 and 3 complex coordinates of H.

   This leads to the identification of the TGD counterparts of scale invariant cosmic perturbation spectrum in terms of dynamical symmetries $g : C^2 \to C_2$ generating new solutions by $f \to g\circ f$.

3. $M^8 - H$ duality [L20] allows to sharpen this vision considerably.

1.4 How to understand the Axis of Evil?

The Axis of Evil, if real, is a profound challenge of cosmology. In TGD inspired cosmology, the exponential expansion of the inflation theory is replaced by quantum coherence in arbitrarily long scales. Quantum coherence in even cosmological scales would explain the approximate constancy of T_{CMB}.

The predicted hierarchy of Planck constants, labelling phases of ordinary matter behaving like dark matter, makes possible quantum diffractive effects in arbitrarily long scales. Could this explain Axis of Evil as a local effect analogous to diffraction. I have already proposed an explanation of the recently observed gravitational hum in terms of diffraction in a lattice-like structure (hyperbolic tessellation) formed by stars [L8].

In the TGD inspired quantum biology the phase transition transforming dark matter to ordinary matter and vice versa are central. In particular, the transformation of dark photons to biophotons plays a key role.

1. Could the multipole coefficients depend also on the space-time sheet of the observer rather than only the history of the CMB photon as the Axis of Evil suggests? Could the space-time

sheet of the observer be identified as the space-time sheet assignable to the entire solar system or its much larger field body? Here one must notice that the age of the solar system is about 4.6 billion years to be compared with the age 13.8 billion years of the Universe.

2. Suppose that one can speak of an ideal CMB for which the dependence of T_{CMB} on the angles $\Omega = (\theta, \phi)$ reflects only the history of the CMB photons. Suppose that the field body associated with the space-time sheet of the observer carries dark CMB photons characterized by a very large gravitational Planck constant. Could their transformation to ordinary photons have an effect on $T(\Omega)$. Could this condensation affect the multipole moments so that they reflect the geometry of the solar system or even larger structure?

3. I have earlier considered the diffraction of gravitational radiation in a lattice-like structure formed by stars to explain the evidence for gravitational hum [L8]: here the "lattice constant" is the average distance about 5 ly between stars. Could the huge values of $\hbar_{gr}$ [E1] [L1] make possible diffraction-like effects in astrophysical scales? Could the quantum coherence in the scale of the solar system or of the proposed stellar lattice make possible diffractive effects for CMB photons and in this vay induce an angle dependent scaling of $T(\Omega)$ inducing the Axis of Evil?

2 Summary of CMB anomalies

It is good to start with a summary of CMB anomalies. Interested readers can easily find nice overall views of anomalies by using Google Search AI. Unfortunately, it also makes mistakes.

For the ideal standard cosmology, Cosmological Principle (CP) implies that apart from local fluctuations predicted by the standard model the CMB temperature is constant. The basic challenge of cosmologists is to find deviations from CP predictions and from the prediction of inflation theory that the spectrum of perturbations is scale invariance. The ΛCDM model, or standard model, makes testable statistical predictions $T_{CMB}(\Omega)$ and various deviations - anomalies - give important hints in attempts to develop a more realistic model of cosmology.

The first deviation from ideality is that the CMB temperature T_{CMB} depends on the direction angles Ω of CMB radiation. This dependence gives valuable information about the cosmic history and about the history of CMB photons arriving from the time of decoupling. In particular, $T_{CMB}(\Omega)$ codes for information about the temperature fluctuations at the time of decoupling giving information about the breaking of CP. Scale invariants of the spectrum is extremely powerful prediction.

$T(\Omega)$, deduced from the fit of the measured frequency distribution of CMB to the black-body-frequency distribution for a fixed Ω, allows to deduce the multipole coefficients of the expansion of $T_{CMB}(\Omega)$ in spherical harmonics. One can compare the multipole coefficients to what can be expected in the standard model predicting the spectrum of fluctuations for T_{CMB}. The lower the multipole, the longer the scale for angular differences $\Delta\Omega$ of which it gives information and the distance between corresponding sources of CMB at the the time $t \sim 380,000$ years when neutral atoms and CMB were formed. The lowest multipoles are dipole, quadrupole and octupole.

1. A particular example of a breaking CP is the correlation of the multipole coefficients with the geometry of the solar system (Axis of Evil).

2. CMB is assumed to define a cosmological rest system and the motion of the solar system with respect to it gives rise to a predictable effect on the measured CMB temperature $T(\Omega)$. The deviations from this prediction are anomalies hinting to a large-scale physics violating CP.

3. The so called matter dipole as an anomaly of matter distribution anomaly provides evidence for the deviation of mass distribution from CP expectation.

4. Also the dark dipole and the recently found quasar dipole provide evidence for collective motion in very long length scales breaking of the CP.

Also statistical anomalies as deviations from the predictions of CP are possible. One can study the fluctuation spectrum of $T(\Omega)$ for a given value of Ω to see whether it is independent of Ω: this kind of dependence means breaking of the CP.

1. The odd streak or hemispherical asymmetry means that the fluctuation powers for the opposite points at Northern and Southern hemispheres are different. This means also that the temperatures after subtracting the CMB dipole are slightly different. The hemispherical power asymmetry can be regarded modulation of the CMB temperature fluctuations, with different power levels in opposite hemispheres of the sky. WMAP and Planck data have consistently identified the direction of the asymmetry.

   A key direction points toward approximately $(l, b) \approx (225°, -27°)$ in galactic coordinates. The direction of this dipole modulation has been found to be largely consistent across different studies and data releases from both WMAP and Planck, confirming its robust statistical presence in the temperature data.

2. Cold spot is a large region of the Southern hemisphere for which CMB temperature is considerably lower. In galactic coordinates the Cold Spot has galactic longitude and latitude given by $(l, b) \approx (209°, -57\circ)$. The width of the cold spot is 5°.

Also the correlation functions $\langle T_{CMB}(\Omega_1)T_{CMB}(\Omega_2)\angle$ can be studied to test whether the prediction of the inflationary scenario for these correlations is correct. The finding that the correlation functions become very small for angle separations larger than 60 degrees serves as an example of this kind of anomaly.

2.1 Dipole anomalies

Consider now the dipole anomalies in more detail.

1. Kinematic dipole of CMB is not an anomaly but due to the motion of the solar system with respect to CMB with a velocity of about 370 km/s. The direction of the dipole is towards the constellation Crater, near its boundary with Leo, whose galactic coordinates are $(l, b) = (276°, 30°$.

   The Doppler effect causes the shift of the frequency of CMB photons and induces a temperature difference between "hot" and "cold" poles in opposite directions, which is about 3.35 millikelvin (mK). Note that the direction of the CMB dipole varies with time since the solar system rotates around the galactic nucleus in the galactic plane.

2. Astronomers also observe a "matter dipole". It is a dipole in the distribution of galaxies and quasars. This dipole is twice as large as the CMB dipole and it doesn't perfectly align with the CMB dipole. The "anomaly" arises since these dipoles are not identical as predicted by CP. This would mean a breaking of CP in very large scales. The direction of this dipole points towards Centaurus near the galactic center Observations of galaxy streams and the "Great Attractor" suggest that part of the constellation, toward galactic coordinates longitude $(l, b) == 307°, 9°)$, lies in the general direction of the galactic center and is heavily populated with galaxies.

   One explanation is that the rest system for the distribution of galaxies and quasars is not the same as that for CMB. The solar system and this system would be moving with different velocities but roughly in the same direction: this could give rise to the matter dipole. Matter dipole in CMB would be due to a Doppler effect for the source of CMB and CMB dipole due to Doppler effect for the receiver. One could also argue that the matter distribution itself has a dipole asymmetry so that the CMB temperature determined by the mass distribution also has a dipole asymmetry.

3. There is also the so-called dark flow anomaly, which relates to the motion of matter. Observations of galaxy clusters suggest a coherent, bulk flow motion of matter in scales of order 2.5 billion ly. The velocity would be about 1000 km/s. This motion is not random, but appears to be directed toward a specific area of the sky. The dark flow could induce the matter dipole as an asymmetry in the distribution of matter and also explain the CMB anomaly.

The direction of the "dark flow" is toward a patch of sky between the southern constellations of Centaurus and Hydra. This direction roughly corresponds to the location of the Great Attractor, a supercluster of galaxies that pulls our own Local Group of galaxies 150–250 million light-years away. Its direction in galacie coordinates is $(l, b) \approx (309^\circ, 18^\circ)$. However, dark flow is claimed to extend much farther than the gravitational reach of the Great Attractor, suggesting it's a distinct phenomenon driven by a more distant or powerful source.

The standard cosmological model predicts that on these scales, the random peculiar velocities of galaxies should average out. The existence of a "dark flow" suggests a gravitational influence from outside the observable universe, potentially from a region beyond the cosmic horizon. Its existence remains controversial, with some studies disputing the findings.

4. Quasar anomaly is a new dipole type 4.9 σ anomaly. Quasar dipole is roughly orthogonal to the kinematic CMB dipole due to the motion of the solar system with respect to the CMB whose direction varies as the solar system rotates around the galaxy but is parallel to the galactic plane. The inferred speed is significantly faster (about 1700 km/s than about 370 km/s for CMB dipole). These two dipoles cannot be explained simultaneously in terms of motion of the solar system with respect to CMB. A coherent motion in long length scales causing a redshift or blueshift of the CMB could be in question.

2.2 Axis of Evil

The quadrupole $l = 2$ and octopole $l = 3$ are the largest-scale multipoles representing the CMB temperature fluctuations. In an isotropic universe, the orientations of these modes should be random. The quadrupole and octopole appear to be unexpectedly aligned with each other and, in some analyses, with the plane of the Solar System (the ecliptic). This alignment has been dubbed the "Axis of Evil".

The Axis of Evil for the aligned quadrupole and octupole moments of temperature distribution is parallel to the ecliptic plane. The Ecliptic plane is tilted relative to the galactic plane by 60 degrees. This relates to the matter distribution. The galactic plane and ecliptic plane are not aligned; they intersect at an angle of approximately 60 degrees. The ecliptic is the plane of our solar system's orbit, which is tilted relative to the galactic plane, the disk of our Milky Way galaxy. This angle is a result of the random orientation of the solar system's formation relative to the galaxy's formation.

In the galactic coordinates, the direction of the Axis of Evil is $(l, b) \approx (202^\circ, 25^\circ)$ and is in ecliptic plane in good approximation. Quadrupole and octupole moments and direction associated with the strongest variation in ecliptic plane.

This suggests a preferred direction in space, which would be a fundamental breaking of the cosmological principle, the idea that the universe is statistically the same in all directions. The significance of this finding has fluctuated as different data and statistical methods have been used, but it remains an intriguing puzzle.

It should be noticed that the directions in galactic coordinates for the hemispherical asymmetry *resp.* cold spot *resp.* Axis of Evil are $(l, b) \approx (225^\circ, -27^\circ)$ *resp.* $(l, b) \approx 209^\circ, -57^\circ)$ *resp.* $(l, b) \approx (202^\circ, 25^\circ)$. The projections of these directions to the galactic plane are rather near to each other. Cold spot is in the direction of constellation Eridanus: could this relate to a common explanation for these anomalies.

2.3 Statistical anomalies

2.3.1 Fluctuation anomalies

Odd streak or hemispherical asymmetry means that there is a temperature difference between the two hemispheres of the sky (see).

Also the scales of the temperature fluctuations at two hemispheres are slightly different. For the spherical asymmetry, the scale of the temperature fluctuations ΔT is 10^{-5} K. This scale of ΔT is by a factor 10^{-2} smaller than the predicted temperature difference ΔT_{pr} between opposite directions due to the motion of the solar system with respect to CMB. It is also much smaller than the CMB anomaly ΔT_{ano}, which is in the same direction and is roughly by a factor 2 larger than ΔT_{pr}. This difference could reflect different degrees of coherence in the two hemispheres.

2.3.2 Anomalies related to the correlations in angle degrees of freedom

The correlation functions $\langle T(\Omega_1)\rangle T(\Omega_2)\rangle$ provide information about the long range (large angle difference) fluctuations of the CMB spectrum. There are various "anomalies" as the angle difference $\Omega_1 - \Omega_2$ increases. The hemispherical asymmetry is one such anomaly.

2.3.3 Low quadrupole and large-scale power suppression

The angular power spectrum of the CMB is expected to have a certain amount of power (variance of temperature fluctuations) at all scales. The lowest multipole, the quadrupole ($l = 2$), corresponds to the largest angular scales. Observations from WMAP and Planck show that the quadrupole has an unusually low amplitude compared to the predictions of the standard model. While the statistical significance of this anomaly on its own has been debated, it contributes to a general finding that there is less power on the largest angular scales than the theory predicts.

More generally, in the ΛCDM model there is an unexpected lack of correlation of fluctuations at very large angular separations (larger than 60 degrees). This could reflect the many-sheeted space-time and the absence of quantum coherence for disjoint space-time sheets.

2.3.4 The CMB cold spot

CMB clod spot is a particularly large region of unusually low temperature fluctuations in the southern celestial hemisphere, in the direction of the constellation Eridanus. The cold spot is about 70 μ K) colder than the average CMB temperature, and its unusually large size and depth are statistically improbable if temperature fluctuations follow a standard Gaussian distribution.

Using galactic coordinates, which measure position relative to the Milky Way's galactic plane, the Cold Spot is centered approximately at $(l, b) = (207.8^{circ}, -56.3^{circ}$. The spot has a radius of about 5^{circ}. The area is also known to contain the "Eridanus Supervoid," a massive region of space with a lower-than-average density of galaxies and matter.

While the supervoid is believed to be the cause of the Cold Spot via the Integrated Sachs-Wolfe effect (or rather, its reverse), recent studies suggest it may not be large enough to explain the full extent of the temperature anomaly. Other, more exotic explanations include the gravitational imprint of a colliding parallel universe.

3 The TGD view of the CMB anomalies

TGD leads to a view of the formation of galaxies, stars and planets different radically from the standard view [L10, L2, L6, L7]

3.1 What the scale invariant spectrum of perturbations does mean in the TGD framework?

What could the notion of scale invariant spectrum of perturbations mean in the framework provided by holography = holomorphy vision (H-H) and zero energy ontology (ZEO) in which there is a fractal hierarchy of causal diamonds CD=$cd \times CP_2$, where cd is the intersection of future and past directed light-cones inside which the space-time surfaces defining the perceptive field of conscious entity. *cd*:s give rise to a Russian doll cosmology.

1. The space-time surfaces obey holography and correspond to slightly non-deterministic Bohr orbits which begin from the boundary of CD. If the primordial cosmology is cosmic string dominated, the space-time surfaces near the boundary of *cd* have a 2-D string world sheet as M^4 projection.

2. Conformal invariance means local scale invariance. In TGD, scale invariance generalizes to a generalized conformal invariance realized in terms of holomorphy= holography hypothesis [L9, L13, L18, L11, L19] in which analytic functions of a hypercomplex coordimate and 3 complex coordinates of H play a key role. Therefore on expects strengthening of the predictions of the scale invariance.

3. As one approaches the boundary of CD its is natural to use Hamilton Jacobi coordinates for which $(u, v) = (t + r, t - r)$ define two light-like coordinates as hypercomplex coordinate and its conjugate and the complex coordinate of the the 2-sphere for the hyperbolic 3-space H^3 defines a complex coordinate w of M^4. Let us assume that $v = 0$ holds true at δcd. At δcd. the metric degenerates to effectively the 2-D metric of sphere $S^2(r)$ since the radial direction is light-like.

4. At quantum level there is hyperbolic conformal invariance with respect to the $u = t + r$ or $v = t - r$: only u or v appears in the polynomials defining X^4. Hypercomplex conformal invariance for $v = t - r$ means that the possible deformations are constant along the radial direction r.

   There is ordinary conformal symmetry with respect to w as a complex coordinate for $S^2(r)$. The strict conformal invariance with respect to w would imply that the perturbations have no w dependence.

How does the scaling invariance of the spectrum of perturbations of the inflation theory translate to TGD? Note first that is important to distinguish between conformal symmetry for X^4 and for the conformal invariance for the spectrum of perturbations of X^4.

X^4 obeys hypercomplex analyticity with respect to $u = t+r$ or $v = t-r$. One can speak of surfaces X^4_u and X^4_v. Conformally invariant perturbations δcd depend on u *resp.* v for X^4_u *resp.* X^4_v. One has $v = 0$ at δcd so that the perturbations X^4_v do not depend on r and for X^4_v and there is a scaling invariance of perturbation with respect to the radial scaling rd/dr. u varies along δcd implying the violation of the scaling invariance for the perturbations of X^4_u. The analogs of plane wave perturbations $exp(ik \cdot x) = exp(ikrcos(\theta))$ are the basic building blocks defining the partial wave coefficients of $T_{CMB}(\Omega)$. They should make sense at the light-cone boundary. All 4 kinds of analycities for the polynomials determining the space-time surface are possible and give rise to 4 types $X^4_{a,b}$, $a \in \{u, v\}$, $b \in \{w, \overline{w}\}$. There the perturbation can depend on (a, b). The dependence of b is via $cos(\theta)$, which corresponds to a spherical coordinate for $S^2(r)$. By hypercomplex conformal symmetry k is identifiable as a spatial component of a light-like vector k in a radial direction. The amplitude varies for $X^4_{u,..}$ $exp(ikrcos(\theta))$ and breaks conformal invariance of the perturbation with respect to w and u. It is however consistent with 4-D conformal symmetry at the level of the "world of classical worlds" (WCW). The Fourier amplitude $f(k)$ is constant by scaling invariance so that scaling invariance in k-space is true. The multipole coefficients C_l for these perturbations are identical with those in the case of inflation theory.

How could the perturbations be realized? Here the symmetries assignable to the holography = holomorphy vision provide guidelines.

1. The space-time surfaces are defined as the roots of analytic functions (f_1, f_2) of hypercomplex coordinate (u or v) of M^4 and 3 complex coordinates (w, ξ^1, ξ^2) of $M^4 \times CP_2$. Both analyticity and anti-analyticity for hypercomplex coordinate and w and CP_2 coordinate pair (ξ^1, xi^2) are possible.

2. The complex analytic maps $g : C^2 \rightarrow C^2$ mapping $f = (f_1, f_2)$ to $g \circ f = g \circ (f_1, f_2)$ are dynamical conformal symmetries and give rise to complexity hierarchies of space-time surfaces. These maps define deformations of the space-time surfaces. Could they define the TGD counterpart or generalization of scale invariant spectrum of perturbations?

3. $M^8 - H$ duality [L20] leads to the proposal that the moduli space of Hamilton-Jacobi structures parametrized by the local group $G_2/U(2)$. Here G_2 is the automorphism group of octonions acting on M^8 identified as octonions with number theoretic inner product defined by $Re(o_1 o_2)$ and $U(2)$ is the subgroup of color group $SU(3) \subset G_2$ acting also as electroweak group.

   The octonion analytic functions $f(o)$ allow to identify the simplest associative 4-surfaces, mapped to H by $M^8 - H$ duality, as the roots $f(o) = 0$. The functional compositions of $f \circ g$ and iterations $f \circ f ... \circ f$ give new associative surfaces. The commutativity $f \circ g_2) = g_2 \circ f$

allows to generate from these surfaces a huge number of similar surfaces by applying local G_2 elements g_2. The function can be taken to be analytic with respect to the Hamilton-Jacobi structure of M^8 defining its generalized complex structure so that H-J structure makes sense at both M^8 and H sides.

4. Generalization of Langlands duality to 4-D context [L9, L13] suggests that the local G_2 leaves the classical action defining the space-time surfaces as Bohr orbits invariant in H and that classical action has an expression as discriminant for polynomial or even analytic function $f(o)$ defined as a product of root differences. This would mean huge conformal invariance.

   By Noether's theorem, the symmetries of action imply conservation laws. Could they be assigned with local G_2 symmetries as a generalization of color symmetry. This would mean a huge degeneracy of classical action. At the H side the analytic maps $g : C^2 \rightarrow C^2$ act as dynamical symmetries and do not leave the action invariant. Could these correspond to the deformations of space-time surfaces appearing also as cosmological perturbations.

3.2 How CMB carries information about its history?

How can the CMB carry information about where the CMB photon came from? In standard cosmology, CMB was created about 380,000 years ago in recombination when neutral atoms would have been formed. Inflation theory tells that the fluctuations of CMB temperature would be coded to the observed CMB spectrum as primordial temperature fluctions.

The spectrum contains also information about what happened to the CMB photons durings its travel. Gravitational lensing of CMB affects the temperature and polarization patterns of CMB. Integrated Sachs-Wolff effect is also involved. The photons travel through regions with varying matter densities and the travel through a gravitational well induces integrated Sachs- Wolf effect as a redshift induced a change of CMB temperature. What happens that gravitational potential flattens during the cosmic expansion and photon does not lose so much energy when climbing from the potential well than falling to the well. Hence a blueshift takes place.

In the TGD framework, the zero energy ontology (ZEO) allows a more concrete interpretation. Space-time is replaced with a union of slightly non-deterministic space-time surfaces representing analogs of Bohr orbits of particles understood in avery general sense. Also photons correspond to this kind of Bohr orbits. In principle, this would give rise to "memory" allow photon to "remember" its geometric past.

If long scale quantum coherence is resposible for the almost constancy of CMB temperature, the quantum coherence would be slighly smaller for the second hemisphere. The physical challenge is to see whether the notion of many-sheeted space-time could explain this. CMB is characterized by temperature as function of direction angles $\Omega = (\theta, \phi)$ parametrized by the multipole coefficients. One should have an intuitive view of how the multipole coefficients depend the associated space-time sheets. Also the field bodies are involved.

3.3 Axis of Evil

The Axis of Evil for the aligned quadrupole and octupole moments of temperature distribution is parallel to the ecliptic plane. This is in sharp conflict with CP. The ecliptic plane is tilted relative to the galactic plane by 60 degrees. This relates to the matter distribution. The galactic plane and ecliptic plane are not aligned; they intersect at an angle of approximately 60 degrees. Why would the ecliptic plane of the solar system have such an unexpected role?

Many-sheeted space-time certainly implies the failure of the strict form of CP. The challenge is to understand the detailed mechanism of the breakdown of CP at the level of the space-time surfaces implied by its replacement with Poincare invariance in H. Could the notion of many-sheeted space-time explain various anomalies?

1. It would seem that CMB must reside on all space-time sheets of the many-sheeted space-time. This suggests that the rest system defined by CMB depends on the space-time sheets, which can move since it is possible to apply Lorentz transformations to the space-time sheets. This could help to understand various dipole anomalies.

2. Number theoretic view of TGD predicts also a hierarchy of effective Planck constants h_{eff} characterizing number theoretical complexity assigned with polynomials defining the space-time sheets. In particular, one can assign gravitational *resp.* electric Planck constant $\hbar gr$ *resp.* $\hbar em$ to long range gravitational [L3] *resp.* electric [L4] fields. $\hbar gr$ *resp.* $\hbar em$ are assigned with field bodies replacing in TGD framework Maxwellian fields. This replacement has highly non-trivial predictions such as monopole flux tubes.

3. Are the CMB photons associated with the field bodies characterized by $\hbar gr$ *resp.* $\hbar em$? This would mean a large-scale quantum coherence and quantal diffraction effects reflecting the structure of the space-time sheets at the level of CMB photons and leaving a signature to its Bohr orbits as an orbit of partonic 2-surface.

Could one understand the localization of the principal octupole and quadrupole axes in the ecliptic plane in terms of some gravitational field body associated with the planetary system? Could the very large value of $\hbar_{gr}$ [E1] [L1] make these kinds of effects.

1. In TGD, the field body gives a kind of geometric individuality for any system, even planetary systems. In Maxwell's theory this is not the case since the fields of different systems interfere. Intuitively it is clear that the gravitational field body can be considerably larger than the planetary system itself. What determines its size?

2. In the detection, a CMB photon must end up in the space-time sheet of the observer. If the CMB photon resides at the space-time sheet of the gravitational field body, it must transform to an ordinary CMB photon in a transition $\hbar_{gr} \rightarrow \hbar$. This is analogous to a transformation of a dark photon to an ordinary photon identified as a biophoton.

3. What is the energy density of CMB at the field body? The spectral energy density defined as energy density per unit volume and per unit photon energy e $u(e,T) = d^2E/dVde$ of Black body radiation is $8\pi f^3/(exp(E/T-1)$. $f = E/h_{eff}$. $u(e,T)$ scales as h_{eff}^{-3} and becomes very small for very small for very large values of h_{eff}. However, if a phase transition $\hbar_{gr} \rightarrow \hbar$ occurs, the energy density increases to that for ordinary black body radiation.

   Could this kind of phase transition take place and give to the higher multipoles a contribution reflecting the quantum coherence at the field body of the ecliptic plane reflecting the properties of the ecliptic plane, which could be considerably larger than the ecliptic plane itself? Could these properties relate to the gravitational fields of the Sun and planets? Could one understand the unexpected smallness of these multipoles in this way?

One can see test this picture by making a quantitative estimate.

1. The gravitational Planck constant for a Sun-particle pair is given by $\hbar_{gr}(S,p) = GM_Sm/\beta_0$, where one has $\beta_0 \simeq 2^{-11}$ and m is the mass of the particle. Quantum gravitational Compton length $\Lambda_{gr} = GM/\beta_0$ defines the minimal quantum coherence length for a particle with mass m. The actual quantum coherence length can be much longer than Λ_{gr}. This is the case in Nottale's model for the planetary system as a gravitational analog of a hydrogen atom.

2. What could be the counterpart of mass m for a CMB photon. The first guess is that m can be replaced with its energy e. For the Sun, which is an essential part of the ecliptic plane, this would give for the gravitational Compton length of CMB photon $\Lambda_{gr} = GM/\beta_0 \simeq 6 \times 10^3$ km which is quite near to the Earth radius 6,371 km. One expects that Λ_{gr} defines the minimum quantum coherence length for the particle.

3. The CMB photons associated with the field body of the ecliptic plane code information about the solar system itself. For instance, the choice of the quantization axis of angular momentum fixes the ecliptic plane.

What could fix the direction of the Axis of Evil?

1. In galactic coordinates, the directions for the hemispherical asymmetry *resp.* cold spot *resp.* Axis of Evil are $(l,b) \approx (225°, -27°)$ *resp.* $(l,b) \approx 209°, -57°)$ *resp.* $(l,b) \approx (202°, 25°)$. The projections of these directions to the galactic are rather near to each other. Maybe this has some significance. For instance, one can ask whether this direction could correspond to a direction associated with a lattice-like structure.

2. Cold spot is in the direction of constellation Eridanus. The distance to the constellation Eridanus varies because it is a large area of the sky, but some of its notable stars are at different distances: the star Epsilon Eridani is about 10.5 light-years away, the star Alpha Eridani) is about 144 light-years away. Some galaxies within the constellation are much farther away, such as the Eridanus Supervoid, which is 6 to 10 billion light-years distant possible.

3. The model for the gravitational diffraction proposed as an explanation of the gravitational hum [L8] involves the assumption that stars form lattice like-structures, or tessellations associated with hyperbolic 3-space H^3 as cosmic time constant surfaces. The gravitational field body of the solar system could correspond to the size of the lattice cell of this lattice. The average distance between stars is about 5 ly.

4. What comes to mind is that there could be a bundle of long cosmic strings connecting the solar system to a star in the direction of the Axis of Evil. This cosmic string need not be the same as the proposed cosmic string in the galactic plane if there is a lattice-like network of stars in which cosmic strings serve as bonds connecting the lattice points.

   (a) Epsilon Eridani has galactic coordinates $(l, b) = (197.82°, -34.3^{circ})$ and is at a distance of 10.5 ly from the solar system. Epsilon Eridani is at the "wrong" side of the galactic plane and cannot relate to the Axis of Evil. It could however belong to a lattice-like structure.

   (b) There is a red dwarf EZ Aquarii in the direction of the Axis of Evil in the constellation Aquarius at a distance of 11.27 light-years.

   (c) Proxima Centauri is the closest star in the constellation Centaurus, at a distance of 4.24 light-years . The galactic coordinates of Proxima Centauri are $(l, b) = (313.926°, -1.918°)$.

3.4 Matter dipole, dark flow and quasar anomaly

Could the quasar dipole be similar to the matter dipole and correspond to a long cosmic string orthogonal to the galactic plane and therefore also orthogonal to the kinematic CMB dipole due to the motion of the solar system in the galactic plane. Also the matter dipole is a good approximation in the galactic plane. Could matter and quasar dipole dipoles correspond to the predicted free flow of matter along two approximately orthogonal long cosmic strings whose intersection would have created the Milky Way nucleus.

The intersection would correspond to the galactic nucleus and blackhole. The formation of the intersections of space-time surfaces consisting of a discrete set of points is probable since cosmic strings moving in 3-space and sufficiently near to each other tend to intersect for purely topological reasons. As a matter of fact, holography= holomorphy vision predicts that space-time surfaces with the same Hamilton-Jacobi structure [L5] intersections are 2-D string world sheets.

Could one understand the approximate alignment of the matter dipole and CMB dipole due to the motion of the solar system around the galactic nucleus or is it mere accident? The direction of the CMB dipole varies as the solar system rotates around the galactic nucleus. The cosmic string in the galactic plane is expected to perform differential rotation but its direction is expected to become constant at larger distances. Therefore the CMB - and matter dipoles would be in the galactic plane but should have different directions.

3.5 Fluctuation anomalies

The odd streak is a large-scale, statistically persistent anomaly in the background temperature fluctuations after the kinematic dipole has been subtracted from the map. The strengths of the temperature fluctuations at Northern and Southern hemispheres, assumed to be due to the primordial density functions, have slightly different strengths. The occurrence of the asymmetry challenges the cosmological principle (see) (see).

The new analysis using the latest Planck data, reaffirmed the hemispherical power asymmetry at low multipoles (large angular scales). The analysis confirms that the effect is not an instrumental artifact and is present with a significance of roughly 2σ.

For the spherical asymmetry, the scale of the temperature fluctuations ΔT is 10^{-5} K. This scale of ΔT is by a factor 10^{-2} smaller than the predicted temperature difference ΔT_{pr} between opposite directions due to the motion of the solar system with respect to CMB. It is also much smaller than the CMB anomaly ΔT_{ano}, which is in the same direction and roughly by a factor 2 larger than ΔT_{pr}.

The spherical asymmetry can be modelled as a dipole modulation replacing the symmetric fluctuation $s_{symm}(\Omega)$ with a more general fluctiuation $s(\Omega) = \Delta(\Omega)T_{symm}/T$ with its dipole modulation $(1 + Acos(\theta))s_{symm}(\Omega)$. This implies the asymmetry $s(\theta)) - s(\pi - \theta)) = 2As_{symm}cos(\theta)$. Here s_{symm} is obtained by subtracting the CMB dipole.

The dipole modulation appears in very long length scales and leads to ask whether the fluctuations are due to a modulation of CMB by the presence of a space-time sheet larger than the scale of horizon for "our" space-time sheet.

1. One option is that the transition leading to the generation of CMB proceeds as a front from the Southern to Northern hemisphere so that the CMB from the Southern Hemisphere is slightly older. From $T(a) \propto 1/a$ one obtains $\Delta a/a = \Delta T/T = x \times 10^{-5}$. From $a \geq t = \int \sqrt{g_{aa}}da$ and $t \sim 3.8 \times 10^5$ years one has $a > t$. $\Delta a = a \times \Delta T/T$ years. The value of the radius of the observable Universe was about $a \simeq 42 - 43$ million years at that time. This gives $\Delta a \sim x \times 420 - 430$ years. The phase transition proceeded through length scale a in time Δa so that the velocity of the phase transition front exceeded light velocity by a factor $T/\Delta T$.

2. A causal signal, whose direction varies, from a higher level of the hierarchy of space-time sheets could induce this kind of phase transition in a quantum critical system. A simple example is the motion of a light spot in the roof. What unvoidably comes to mind is a sentence from the creation narrative: "Let there be light. And the light came".

This kind of mechanism might apply also to other anisotropies of the CMB, which are not due to Doppler effect. The temperature fluctuations ΔT would correspond to the fluctuations Δa for the time for the generation of the seed of the phase transition leading to the emergence of CMB. For instance, in the case of the cold spot this would mean that galaxies in this region are created considerably earlier than elsewhere.

One example of this is provided by a research presented in June 2024 and subsequently published [E2] (see this) identified a previously unknown extragalactic foreground that correlates with the positions of nearby spiral galaxies.

Astronomers have found a systematic decrease in CMB temperature around nearby large spiral galaxies. The standard view suggests an unknown interaction is occurring between CMB photons and these galaxies on megaparsec scales. Could it be that the nearby large spiral galaxies were born earlier than other galaxies? This could correlate with their large size. The TGD view about the formation of galaxies as thickenings of long flux tubes giving rise to tangles could conform with this picture. The phase transition could have started near the galaxies and have proceeded outwards.

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