Correlated Polygons in Standard Cosmology and in TGD

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Abstract

The recent proposal of Maldacena and Arkani-Hamed is that cosmic microwave background (CMB) might contain signature of inflationary cosmology as triangles and polygons for which the magnitude of n-point correlation function is enhanced. In the proposal of Maldacena and Arkani-Hamed the polygons are defined by momentum conservation. In TGD framework inflationary cosmology is replaced with rather different approach and inflaton field is not needed.

Also in TGD one ends up with polygons but from quite different starting point. The Kähler magnetic fluxes through areas defied by polygons at partonic 2-surfaces would define symplectic invariants and the polygons would be fixed rather uniquely by requiring that fermions reside at their vertices so that momentum conservation would not be involved. 3-, 4- and 5-polygons are prime polygons in the sense that any polygon can be sliced to these polygons but these polygons do not allow slicing to non-degenerate polygons. Non-degenerate polygons represent integers and one can regard 3, 4, and 5 as additive primes. This representation of integers - probably discovered by mathematicians - could have some relevance for Diophantine equations. This leads to an idea about connection with arithmetic consciousness discussed in separate context.

1 Introduction

Peter Woit had an interesting This Week's Hype (see http://tinyurl.com/hmmj9bp). The inspiration came from a popular article in Quanta Magazine (see hhttp://tinyurl.com/jhd5xpe) telling about the proposal of Maldacena and Nima Arkani-Hamed that the temperature fluctuations of cosmic microwave background (CMB) could exhibit deviation from Gaussianity in the sense that there would be measurable maxima of n-point correlations in CMB spectrum as function of spherical angles. These effects would relate to the large scale structure of CMB. Lubos Motl wrote about the article in different and rather aggressive tone (see http://tinyurl.com/zzwt6ou).

The article in Quanta Magazine does not go into technical details but the original article of Maldacena and Arkani-Hamed [B2] (see https://arxiv.org/pdf/1503.08043v1) contains detailed calculations for various n-point functions of inflaton field and other fields in turn determining the correlation functions for CMB temperature. The article is technically very elegant but the assumptions behind the calculations are questionable. In TGD Universe they would be simply wrong and some habitants of TGD Universe could see the approach as a demonstration for how misleading the refined mathematics can be if the assumptions behind it are wrong.

It must be emphasized that already now it is known and stressed also in [B2] that the deviations of the CMB from Gaussianity are below recent measurement resolution and the testing of the proposed non-Gaussianities requires new experimental technology such as 21 cm tomography [B1] (see http://arxiv.org/abs/0802.1710) mapping the redshift distribution of 21 cm hydrogen line to deduce information about fine details of CMB now n-point correlations.

Inflaton vacuum energy is in TGD framework replaced by Kähler magnetic energy and the model of Maldacena and Arkani-Hamed does not apply. The elegant work of Maldacena and Arkani-Hamed however inspired a TGD based consideration of the situation but with very different motivations. In TGD inflaton fields do not play any role since inflaton vacuum energy is replaced with the energy of magnetic flux tubes. The polygons also appear in totally different manner and are associated with symplectic invariants identified as Kähler fluxes, and might relate closely to quantum physical correlates of arithmetic cognition. These considerations lead to a proposal that integers $(3, 4, 5)$ define what one might called *additive primes* for integers $n \geq 3$ allowing geometric representation as non-degenerate polygons - prime polygons. On should dig the enormous mathematical literature to find whether mathematicians have proposed this notion - probably so. Partitions would correspond to splicings of polygons to smaller polygons.

These splicings could be dynamical quantum processes behind arithmetic conscious processes involving addition. I have already earlier considered a possible counterpart for conscious prime factorization in the adelic framework [L4]. This will not be discussed in this section since this topic is definitely too far from primordial cosmology. The purpose of this article is only to give an example how a good work in theoretical physics - even when it need not be relevant for physics - can stimulate new ideas in completely different context [L3].

2 Could cosmic microwave background exhibit non-local correlations?

It is good to start by summarizing my understanding about the basic ideas in the work of Maldacena and Arkani-Hamed [B2] (see https://arxiv.org/pdf/1503.08043v1). Besides inflationary scenario the existence of very massive particles with mass of the order of inverse Hubble radius during inflationary period or even before it are assumed. They would correspond to massive excitations of superstrings. These very massive particles would decay to inflatons and these couplings would make possible non-trivial $n > 2$ point correlation functions for inflaton field. These correlations would in turn be inherited by the cosmic energy density and thus correlation functions of CMB temperature. There would be a tendency for the appearance of triangles and higher polygons for which maximum for the modulus of the n-point correlator and the hope would be that these maxima could be detected some day in CMB spectrum.

The correlation functions are calculated in de-Sitter background - e de-Sitter space is a good model for inflationary period and one can use the symmetries of de-Sitter space to make rather detailed conclusions about the general form of correlation functions.

One has only 3-D translational invariance since time translation is not isometry of de-Sitter space. By this symmetry one can perform Fourier transformation and n-point correlation functions in momentum space vanish only at points in which the sum of momenta vanishes. Momenta therefore define a closed polygon - triangle, square, etc... in momentum space. Besides 3-D translational invariance there is also 3-D conformal invariance. As in the case of 2-D conformal invariance, one can deduce the general form of lowest n-point functions highly uniquely for any spin (string excitations can have arbitrarily high spin) in both momentum space and x-space.

There is analogy analogy to what particle theorists are doing at LHC: in this case four-momentum conservation gives similar constraint and define polygons in four-momentum space. The correlation functions of fields define the scattering amplitudes. In cosmology one is interested on extracting non-trivial n-point correlations from the background. These special configurations would correspond to squeezed triangles. At LHC final state particles with very large transversal momentum would be an analogous source of information.

One could say that inflationary period defines a cosmic particle accelerator and that the scatterings, which have taken near to the end of the inflationary period are visible in CMB: this because the exponential expansion would have destroyed the memories about earlier times. The cosmic particle experiment would end, when inflationary period ends. From the graph of Wikipedia article (see `http://tinyurl.com/odlpyg8`) one learns that this would correspond to Hubble radius $1/H$ of order $1/H = 10^{-25}$ meters so that the mass of the massive string excitations would be larger than mass of about $H_{min} \sim 10^{10} \times m_p$ or about 10^{-9} Planck masses.

The article in Quanta Magazine suggests that the triangles correspond to triplets of hot spots in CMB: maybe this follows from the assumption that the modulus correlation function is maximum. I do not quite understand this. There is correlation between values of temperature but this does not imply that temperature at the hot spots would be higher and same. It is mentioned that the so called cosmic fluctuations might make it impossible to detect these basically quantal correlations.

3 Early cosmology in TGD framework

In TGD framework polygons interpreted in terms of enhanced correlations of inflaton field do not appear in cosmology since inflaton field is not needed. Momentum conservation gives rise to polygons also now but they will not be considered in the sequel. In TGD framework the physical picture is very different although inflation has TGD analog and also causal diamonds (CDs) serving as key geometric element of Zero Energy Ontology (ZEO) are bring in mind Big Bang followed by Big Crunch.

1. The starting point is the fact cosmic temperature is constant with variations of order $\Delta T/T \sim 10^{-5}$. Inflationary theory was born to explain this miracle in terms of exponential expansion destroying all details of the primordial temperature distribution.

2. Also in TGD framework the analog for the exponential expansion is predicted but it would not be needed to explain the constancy of the temperature as resulting of smoothing out of fluctuations. Temperature fluctuations would reduce to fluctuations for the beginning of the transition to the radiation dominated phase.

   The primordial state preceding the TGD analog of inflationary period would be gas of cosmic strings having arbitrarily long lengths and form a fractal structure - this is new and makes sense because the size of horizon is infinite in M^4. Cosmic strings could serve as correlates for quantum entanglement and an elegant explanation for the constancy of temperature would be in terms of quantum coherence in cosmic length scales involving negentropic entanglement (NE) and hierarchy of Planck constants $h_{eff} = n \times h$. This together with Zero Energy Ontology (ZEO) leads to a TGD analog of the cyclic cosmology with entire cosmos regarded as conscious entity [K4] [L2]. In the cyclic cosmology the cosmic strings near the boundary of CD would not be any more free cosmic strings but magnetic flux tubes and every period of cycle would make them thicker so that genuine evolution would take place instead of boring repetition.

   The analog of the inflationary period corresponds to a creation of space-time in GRT sense. Space-time sheets with 4-D M^4 projection are generated and gas of cosmic strings topologically condensed at them and starts (or continues) transformation to (thicker) magnetic flux tubes. In other words, 2-D M^4 projection (string world sheet) begins to grow in thickness. Ordinary matter emerges from the decay of the magnetic energy of cosmic string to ordinary particles during this period and the analog of inflationary cosmology would describe this matter (it is not quite clear whether also the energy of topologically condensed cosmic strings is included).

3. The magnetic energy density of flux tubes replaces the vacuum energy density of inflaton fields in TGD framework. The massive particles (string excitations) decaying to inflatons correspond to topologically condensing cosmic strings carrying conserved monopole flux. Their magnetic energy decays to particles as their thickness grows and magnetic field strength and therefore also magnetic energy density per unit length is reduced.

   Magnetic flux tubes would be present also in the recent cosmology and form basic building bricks of various astrophysical structures. For instance, galaxies would be string like objects, which are like pearls in a necklace formed by long string like objects at the boundaries of large voids. The sensational news would be that the primordial stringy structures are directly visible in the recent cosmology and seen long time ago! No statistical description is needed and if possible it must take into account the fractality realized in terms of p-adic length scale hierarchy and hierarchy of Planck constants, which is of course one of the predictions.

4. TGD suggests a model for the transition from the gas of cosmic strings to the radiation dominated cosmology as Robertson-Walker cosmology in terms of vacuum extremal having interpretation as critical or over-critical cosmology in GRT framework [K4]. This cosmology is unique apart from its finite duration. Mass density approaches infinite value before a transition to Euclidian signature of induced metric would happen (TGD interpretation could be in terms of TGD analog of blackhole). The condition that the energy density of space-time surface does not exceed that of cosmic strings in M^4 implies that the transition to radiation dominated cosmology takes place already earlier.

   This cosmology would replace the de-Sitter cosmology in the model of Maldacena and Arkani-Hamed if the notion of inflaton field would make sense. The critical cosmology has flat 3-space and in this case one could apply momentum conservation but energy conservation would not apply. The conservation law of 3-momentum applies at space-time level and should not be confused with the fundamental conservation of four-momentum at imbedding space level. QFT at space-time level would be at best an approximation. The modes of quantum fields are replaced with spinor harmonics of imbedding space defining ground state of the super-symplectic representations and one cannot neglect this algebra in the fundamental description using scattering amplitudes coded by zero energy states representable as modes of spinor fields of WCW.

5. The fractal structure of cosmic string condensate implies the failure of QFT description based on point like particles described by inflaton field. Strong form of holography (SH) states that string world sheets and partonic 2-surfaces serve as “space-time genes”. This would suggests that string model in many-sheeted space-time could provide a fundamental description for the topological condensation and decay of cosmic strings to ordinary particles. The “space-time half” (or bulk half) of SH conforms with the idea that the cosmic strings are still there as magnetic flux tubes serving as building bricks of directly observed astrophysical and cosmological structures. For instance, galactic dark matter could be identified as magnetic energy of the long string like object defining the cosmic necklace with galaxies as pearls.

4 How do polygons emerge in TGD framework?

The duality defined by strong form of holography (SH) has 2 sides. Space-time side (bulk) and boundary side (string world sheets and partonic 2-surfaces). 2-D half of SH would suggest a description based on string world sheets and partonic 2-surfaces. This description should be especially simple for the quantum states realized as spinor fields in WCW (“world of classical worlds”). The spinors (as opposed to spinor fields) are now fermionic Fock states assignable to space-time surface defining a point of WCW. TGD extends ordinary 2-D conformal invariance to super-symplectic symmetry applying at the boundary of light-cone: note that given boundary of causal diamond (CD) is contained by light-cone boundary.

1. The correlation functions at imbedding space level for fundamental objects, which are fermions at partonic 2-surfaces could be calculated by applying super-symplectic invariance having conformal structure. I have made rather concrete proposals in this respect. For instance, I have suggested that the conformal weights for the generators of supersymplectic algebra are given by poles of fermionic zeta $\zeta_F(s) = \zeta(s)/\zeta(2s)$ and thus include zeros of zeta scaled down by factor 1/2 [K5]. A related proposal is conformal confinement guaranteeing the reality of net conformal weights.

2. The conformally invariant correlation functions are those of super-symplectic CFT at light-cone boundary or its extension to CD. There would be the analog of conformal invariance associated with the light-like radial coordinate r_M and symplectic invariance associated with CP_2 and sphere S^2 localized with respect to r_M analogous to the complex coordinate in

ordinary conformal invariance and naturally continued to hypercomplex coordinate at string world sheets carrying the fermionic modes and together with partonic 2-surfaces defining the boundary part of SH.

4.1 Symplectic invariants

Symplectic invariants emerge in the following manner. Positive and negative energy parts of zero energy states would also depend on zero modes defined by super-symplectic invariants and this brings in polygons. Polygons emerge also from four-momentum conservation. These of course are also now present and involve the product of Lorentz group and color group assignable to CD near its either boundary. It seems that the extension of Poincare translations to Kac-Moody type symmetry allows to have full Poincare invariance (in its interior CD looks locally like $M^4 \times CP_2$).

1. One can define the symplectic invariants as magnetic fluxes associated with S^2 and CP_2 Kähler forms. For string world sheets one would obtain non-integrable phase factors. The vertices of polygons defined by string world sheets would correspond to the intersections of the string world sheets with partonic 2-surfaces at the boundaries of CD and at partonic 2-surfaces defining generalized vertices at which 3 light-like 3-surfaces meet along their ends.

2. Any polygon at partonic 2-surface would also allow to define such invariants. A physically natural assumption is that the vertices of these polygons are realized physically by adding fermions or antifermions at them. Kähler fluxes can be expressed in terms of non-integrable phase factors associated with the edges. This assumption would give the desired connection with quantum physics and fix highly uniquely but not completely the invariants appearing in physical states.

The correlated polygons would be thus naturally associated with fundamental fermions and a better analogy would be negentropically entangled n-fermion state rather than corresponding to maximum of the modulus of n-point correlation function. Hierarchy of Planck constants makes these states possible even in cosmological scales. The point would be that negentropic entanglement assignable to the p-adic sectors of WCW would be in key role.

4.2 Symplectic invariants and Abelian non-integrable phase factors

Consider now the polygons assignable to many-fermion states at partonic 2-surfaces.

1. The polygon associated with a given set of vertices defined by the position of fermions is far from unique and different polygons correspond to different physical situations. Certainly one must require that the geodesic polygon is not self-intersecting and defines a polygon or set of polygons.

2. Geometrically the polygon is not unique unless it is convex. For instance, one can take regular n-gon and add one vertex to its interior. The polygon can be also constructed in several manners. From this one obtains a non-convex $n+1$-gon in $n+1$ manners.

3. Given polygon is analogous with Hamiltonian cycle connecting all points of given graph. Now one does not have graph structure with edges and vertices unless one defines it by nearest neighbor property. Platonic solids provide an example of this kind of situation. Hamiltonian cycles [?, ?] are key element in the TGD inspired model for music harmony leading also to a model of genetic code [K3] [L1].

4. One should somehow fix the edges of the polygon. For string world sheets the edges would be boundaries of string world sheet. For partonic 2-surfaces the simplest option is that the edges are geodesic lines and thus have shortest possible length. This would bring in metric so that the idea about TGD as almost topological QFT would be realized.

One can distinguish between two cases: single polygon or several polygons.

1. One has maximal entanglement between fundamental fermions, when the vertices define single polygon. One can however have several polygons for a given set of vertices and in this case the coherence is reduced. Minimal correlations correspond to maximal number of 3-gons and minimal number of 4-gons and 5-gons.

2. For large $h_{eff} = n \times h$ the partonic 2-surfaces can have macroscopic and even astrophysical size and one can consider assigning many-fermion states with them. For instance, anyonic states could be interpreted in this manner. In this case it would be natural to consider various decompositions of the state to polygons representing entangled fermions.

The definition of symplectic invariant depends on whether one has single polygon or several polygons.

1. In the case that there are several polygons not containing polygons inside them (if this the case,then the complement of polygon must satisfy the condition) one can uniquely identify the interior of each polygon and assign a flux with it. Non-integrable phase factor is well-defined now. If there is only single polygon then also the complement of polygon could define the flux. Polygon and its complement define fluxes Φ and $\Phi_{tot} - \Phi$.

2. If partonic 2-surface carries monopole Kähler charge Φ_{tot} is essentially $n\pi$, where n is magnetic monopole flux through the partonic 2-surface. This is half integer - not integer: this is key feature of TGD and forces the coupling of Kähler gauge potential to the spinors leading to the quantum number spectrum of standard model. The exponent can be equal to -1 for half-odd integer.

   This problem disappears if both throats of the wormhole contact connecting the space-time sheets with Minkowski signature give their contribution so that two minus-signs give one plus sign. Elementary particles necessarily consist of wormhole contacts through which monopole flux flows and runs along second space-time sheet to another contact and returns along second space-time sheet so that closed monopole flux tube is obtained. The function of the flux must be single valued. This demands that it must reduce to the cosine of the integer multiple of the flux and identifiable as as the real part of the integer power of magnetic flux through the polygon.

The number theoretically deepest point is geometrically completely trivial.

1. Only $n > 2$-gons are non-degenerate and 3-, 4- and 5-gons are prime polygons in the sense that they cannot be sliced to lower polygons. Already 6-gon decomposes to 2 triangles.

2. One can wonder whether the appearance of 3 prime polygons might relate to family replication phenomenon for which TGD suggests an explanation in terms of genus of the partonic 2-surface [K1]. This does not seem to be the case. There is however other three special integers: namely 0,1, and 2.

   The connection with family replication phenomenon could be following. When the number of handles at the parton surface exceeds 2, the system forms entangled/bound states describable in terms of polygons with handles at vertices. This would be kind of phase transition. Fundamental fermion families with handle number 0,1,2 would be analogous to integers 0,1,2 and the anyonic many-handle states with NE would be analogous to partitions of integers $n > 2$ represented by the prime polygons. They would correspond to the emergence of p-adic cognition. One could not assign NE and cognition with elementary particles but only to more complex objects such as anyonic states associated with large partonic 2-surfaces (perhaps large because they have large Planck constant $h_{eff} = n \times h$) [K2].

The identification of prime polygons as geometric representations of "additive primes" for integers $n > 2$ is a number theoretically fascinating idea and the possible connection with the realization of arithmetic consciousness is equally interesting idea to consider but because this would take too far from primordial cosmology it is better to leave this topic to another article [**?**].

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