Conformal cyclic cosmology of Penrose and zero energy ontology based cosmology

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August 17, 2018

Abstract

Penrose has proposed an interesting cyclic cosmology in which two subsequent cosmologies are glued along conformal boundary together. The metric of the next cosmology is related to that of previous by conformal scaling factor, which approaches zero at the 3-D conformal boundary. The physical origin of this kind of distance scaling is difficult to understand. The prediction is the existence of concentric circles of cosmic size interpretable as kind of memories about previous cosmic cycles.

In TGD framework zero energy ontology (ZEO) inspired theory of consciousness suggest an analogous sequence of cosmologies. Now the cycles would correspond to life cycles of cosmic size serving as a conscious entity having causal diamond (CD) as imbedding space correlate. The arrow of geometric time is defined as the time direction to which the temporal distance between the ends of CD increases in sequence of state function reductions leaving passive boundary of CD unaffected and having interpretation as weak measurements. The arrow of time changes "big" state function reductions changing the roles of the boundaries of CD and meaning the death and re-incarnation of self with opposite arrow of time. Penrose's gluing procedure would be replaced with "big" state function reduction in TGD framework. This proposal is discussed in some detail and the possibility that also now concentric low variance circles in CMB could carry memories about the previous life cycles of cosmos. This picture applies to all levels in the hierarchy of cosmologies (hierarchy of selves) giving rise to a kind of Russian doll cosmology.

Contents

1 Introduction

This text was inspired by a popular article "Weird circles in the sky may be signs of a universe before ours" (see http://tinyurl.com/ycme7xg4 telling about the conformal cyclic cosmology (CCC) proposed by Penrose (see http://tinyurl.com/ydbq32) predicting low variance concentric circles in cosmic microwave background (CMB) [E1] (see https://arxiv.org/abs/1808.01740) .

1. 2011 Penrose and V.G. Gurzadyan claimed that CMB indeed contains concentric circles with a low variance. The significance of the finding was told to be 6-sigma (see http://tinyurl.com/ydbz587d.

2. Three groups have independently attempted to reproduce these results, but found that the detection of the concentric anomalies was not statistically significant, in that no more concentric circles appeared in the data than in Lambda-CDM simulations (see `https://arxiv.org/abs/1012.1268`, `https://arxiv.org/abs/1012.1305`, and `https://arxiv.org/abs/1012.1656`). The reason for the disagreement was tracked down to an issue of how to construct the simulations that are used to determine the significance (see `https://arxiv.org/pdf/1012.1486.pdf`): Wikipedia article (see `http://tinyurl.com/jnnwnwv`) tells that the three independent attempts to repeat the analysis all used simulations based on the standard Lambda-CDM model, while Penrose and Gurzadyan used an undocumented non-standard approach.

3. The recent paper by An, Meissner and Penrose [E1] (see `https://arxiv.org/abs/1808.01740`) the earlier claims are repeated and it is also noticed that the B-mode location found by BICEP 2 corresponds to a singular point to which one assign concentric circles of low variance in CMB.

The idea of CCC is mathematically rather refined. The vision is that Universe can be seen as a sequence of cosmologies (aeons as Penrose calls them) obtained by gluing them together. The Robertson-Walker metric of given cosmology would differ from the previous cosmology by a conformal factor Ω^2 approaching zero at smooth space-like conformal boundary, which I understand as the surface at which cosmic time coordinate approaches infinity.

Remark: In the case of M^4 light-cone this conformal boundary could correspond to the limit of the hyperboloid $a = \sqrt{t^2 - r^2} = constant \to \infty$, where a is proper time coordinate of the light-cone. Symmetry of CD in TGD framework suggests that the conformal boundaries correspond to opposite boundaries of CD. It is interesting that the metric restricted at the either boundary of CD becomes formally zero ($ds^2 = da^2 - a^2(d\Omega^2 \to da^2)$ in analogy with conformal scaling factor going to zero.

The presence of the conformal factor would mean that the lengths in the new metric is scaled down by a factor Ω approaching zero. Gluing would not be isometric and infinite shrinking of the scales would take place in the transition. This looks questionable. Penrose justifies conformal gluing by 4-D conformal invariance. But how could physics realize this shrinking of scales? This remains a mystery.

Could CCC be tested?

1. This would require that the previous aeon leaves some memories about itself to the next aeon. These memories should originate from the physical state at the conformal boundary. The view is following. The end of the previous aeon gives rise to a formation of blackholes and in the beginning of the next aeon these blackholes suffer Hawking evaporation as photons. This assumption is claimed to follow from general consistency conditions implying that all fermionic matter must transform to bosonic matter whereas radiation could survive the transition.

2. For instance, the evaporation of galactic blackhole would give rise to enormous pulse of Hawking radiation defining expanding spherical wave front. The photons associated with these wave fronts would modify CMB and give rise to circles with low variance. It is essential that circles are in question and Penrose and Gurzadyan claim that elliptic and triangle like curves with low variance are not found in CMB. Several concentric circles could be seen as evidence for several aeons before the recent one.

3. If the circles really exist, they would have revolutionary implications. The reason is that they have cosmic size scale of the order of the time scale when inflationary period ended and changed to radiation dominance with radiation coming from the energy of inflaton field.

The proposal CCC is highly interesting from TGD point of view. In TGD framework the time scale for the setting of radiation dominated phase would correspond to the time when cosmic string dominated period ended and space-time surfaces with 4-D M^4 projection modellable in terms of radiation dominated cosmology emerged. The thickening of cosmic strings would have reduced string tension and the liberated energy would have transformed to ordinary particles [**?**, K1, K3].

The view is that cosmic strings condensed at the newly formed space-time surfaces and began to thicken as magnetic flux tubes. In zero energy ontology (ZEO) the radiation (ordinary particles) emitted by cosmic strings would be absorbed at the opposite boundary of CD meaning essentially time reversal of the analog of inflationary transition.

CD serves as a correlate for a conscious entity [L2]- self - even in cosmic length scales. Self corresponds to a sequence of state function reductions - analogs of weak measurements - changing only the members of zero energy states assignable to the active (changing) boundary of CD. The death and reincarnation of self means the first state function reduction - "big" reduction in which the roles of passive (unchanging) and active boundaries of CD are changed. In cosmology this would mean re-incarnation of cosmology as cosmology with opposite arrow of time since the former passive boundary becomes the active boundary receding from the passive boundary. The question is whether the process transforming energy of cosmic strings to radiation consisting of ordinary matter during very early CD cosmology can cause spherical radiation pulses and whether these spherical surfaces are preserved as memories from earlier life cycles of cosmic self. I have discussed this idea earlier in [K1] and [L1].

2 ZEO based cosmology as sequence of deaths and reincarnations of cosmology as a conscious entity

TGD inspired theory of consciousness based on zero energy ontology (ZEO) [L2] leads to a quantum variant about sequence of cosmologies.

1. Zero energy states are pairs of quantum states at active and passive boundary and the members of states pairs at passive boundary are not affected whereas those at active boundary change in state function reductions following unitary evolutions. Also the temporal distance between passive and active boundary changes and defines a clock time in correspondence with the subjective time identified as sequence of state function reductions defining moments of consciousness for the conscious entity associated with the CD. One can say that one has Zeno effect for the passive boundary of CD.

2. One can interpret the sequence of state function reductions as weak quantum measurements and argue that if the number of observables to be measure is infinite, eventually the situation in which no state function reduction is possible anymore. What should the conscious entity do. Just repeat the measurement of observables already measured - kind of enlightened state freed from the cycle of Karma - or perform the first state function reduction not leaving the states at the passive boundary invariant. This "big" state function reduction - analogous to ordinary state function reduction in elementary particle physics - would change the roles of the active and passive boundary. Self would die and reincarnate as as self with opposite arrow of clock time. CD would now increase in opposite time direction.

3. CDs can have arbitrarily large sizes and form an infinite hierarchy. Sub-CD corresponds to mental image at the level of conscious experience. Even Universe - or rather hierarchy of Universe - could be seen as a conscious entity. Cosmologies are assignable to causal diamonds (CDs) for which second -passive - boundary remains invariant under a sequence of state function reductions at second - active - boundary analogous to weak measurements.

4. If cosmological selves are part of this "Karma's cycle", one would have the analog of Penrose's CCC. The conformal gluing of space-times would be replaced by the "big" state function reduction replacing zero energy state with a given arrow of time with a state with opposite arrow of time. T symmetry is broken both in physics (neutral kaon and B meson). T is broken also in TGD Universe by the necessity to have generalized Kähler structure for M^4: this gives rise to small CP and T breaking interaction distinguishing between time evolution and its time reversal so that even classically cosmic evolution and its reversal are not same.

2.1 More precise view about ZEO based cosmology

Consider now in more detail ZEO based (sub-)cosmology as conscious entity.

1. One can start from TGD inspired theory of consciousness. Can we remember our lives as meditators claim? One can used the fractality of self hierarchy to reformulate the question. Our mental images have finite lifetime: for sensory mental images this life time is measured in fraction of second. We know the phenomenon of after image: the same mental image -say visual mental image - dies and re-incarnates again and again. Could it be that the period between the two mental images corresponds to time reversal of the corresponding sub-self? Could it be that at some level of the personal self hierarchy I died at the evening, slept the night living in opposite time direction, and woke up at the morning as a reincarnation in the original time direction. I indeed remember things about yesterday and even days before that!

2. Could also cosmic memories be possible? Could recent cosmology remember some dramatic events about its previous life cycle? Penrose considers Hawking evaporation as an event of this kind. In the case of galactic blackhole evaporation near conformal boundary would create a huge pulse of Hawking radiation and these pulses from the previous cosmologies would be responsible for the concentric circles.

   In TGD framework the analogs of these radiation pulses could also be generated as the dark matter and energy inside cosmic strings transforms to ordinary particles at the passive boundary of CD. At the active boundary the reversal of this process would occur as cosmic strings would absorb all the ordinary matter. This process is TGD counterpart for the the transformation of the energy of inflaton field to elementary particles particles and would lead to radiation dominated period and give rise to ordinary space-time.

Zero energy states are superpositions of classical space-time surfaces associated with the zero energy states. A natural expectation is that the space-time surfaces very near the passive boundary are in reasonable approximation free cosmic strings and then make transition to radiation dominated RW cosmology. Same should hold true also at the active boundary.

1. If this occurs in strict sense, the magnetic flux tubes - thickened cosmic strings - serving as correlates for the linear structures formed by galaxies and having galaxies as local knots in turn having stars as local knots would transform back to free cosmic strings containing magnetic and dark energy plus dark matter as $h_{eff} = nh_0$ phases [K2, K4]. This would require very special boundary conditions near the boundaries of CD demanding ing that the elementary particles generated by partial evaporation of cosmic strings during the analog of the inflationary period would be absorbed by cosmic strings to which magnetic flux tubes would be contracted.

2. This process would be analogous to the formation of blackholes as a reversal of their evaporation and of inflationary period near the passive boundary. The process thinning the cosmic strings would also resemble Penrose's downwards conformal scaling of distances by factor $\Omega \to 0$. It must be emphasized that in CCC the blackholes would evaporate and leave only radiation at the future conformal boundary. Here TGD picture would differ radically from the view of Penrose.

3. Boundary conditions at the boundaries of CD stating that near both boundaries of CD one has gas of cosmic strings in CD would force this kind of reversal of the arrow of classical time evolution happen say around $a = T/2$, where T is the distance between tips of CD (which itself increases in every weak measurement). Could these boundary conditions be forced by the preferred extremal property, which is extremely powerful condition indeed. The proposal is that the only allowed extremals are minimal surfaces except at points having interpretation as reaction vertices. These boundary conditions should imply a rough analog of time reflection symmetry with respect to $a = T/2$ (perhaps in statistical sense)

   Remark: In Wikipedia article about CCC (see `http://tinyurl.com/jnnwnwv`) it is mentioned that the existence of smooth conformal horizons in GRT is an extremely powerful condition.

   If this contraction of flux tubes to cosmic strings happens, the beginning of the time reversed cosmic evolution would be rather similar to the previous evolution. In reversed time direction

the contraction process would look like the analog of the inflationary period. The process is quantum process, and one might also ask whether the "big" state function reduction could occur with maximal probability to the time reversed space-time surfaces, which are cosmic strings near the active boundary of CD. For this option boundary conditions would be needed.

4. Could cosmic string dominance be the only possible mathematically acceptable option? In GRT picture, radiation dominance implies that the GRT based energy density diverges like $1/a^4$ and the energy of co-moving volume diverges like $1/a$: this looks non-sensical. For cosmic string dominance the energy density in CD would behave like $1/a^2$ and the energy of a co-moving volume vanishes like a: cosmology would be a "silent whisper amplified to relatively big bang": one can hardly demand anything smoother if one accepts GRT description. Matter dominance would give finite energy per co-moving volume.

   It however turns out that in TGD framework very early cosmology is even simpler. The energy density remains finite near the boundaries of CD and this possible due to that fact that many-sheeted space-time having GRT as an approximate description is replaced with a gas of cosmic strings.

   Remark: Second option is that one obtains in the cosmic re-incarnation only scaled up variants of flux tubes looking cosmic strings in resolution defined by a longer length scale. I have earlier regarded this option as a more realistic one [K1] [L1].

Some comments and questions are in order.

1. CDs form a hierarchy and it is quite possible that one obtains this kind of almost-predictions in all scales.

2. Could the CDs with no outgoing legs be in preferred position and the proposed boundary conditions hold true only for them? One can also ask whether the particles could simply travel through the active boundary out as external particles so that the boundary of CD would contain only the cosmic strings. This would not conform with the idea that the thickening of cosmic strings reducing their string tension generates ordinary matter in analogy with inflation.

3. An essential point is whether one allows CDs to have external legs analogous to incoming particles of particle reaction. These are possible and would give rise to a construction of scattering diagrams analogous to that applied in twistor Grassmannian approach. But zero ZEO also allows to have "irreducible" CDs with not external legs and analogous to vacuum fluctuations in QFT context. These states would be something genuinely new not allowed by ordinary ontology.

4. In the more recent view about dynamics inside CDs I have returned to the original proposal that the minimal surface property of space-time sheets does not hold only true outside CDs for external particles but also inside CDs and that it breaks down only in reaction vertices located at partonic 2-surface [L3]. At these points there is energy transfer between volume term and Kähler action proportional to delta function. Feynman/twistor graph like representation of scattering amplitudes would be realized at classical space-time level. Cosmic strings are the simplest minimal surfaces and come as two kinds and would be the analogs of blackholes in TGD framework. Note that TGD allows the possibility of blackhole like states too but blackhole interior would contain highly tangled cosmic string.

2.2 How the TGD description differs from GRT description near the boundaries of CD

The first questions concern the conservation laws near the boundaries of CD. One expects that GRT cosmology fails near the boundaries of CD as the appearance of singularity suggests. I have indeed proposed the description of very early cosmology in terms of gas of cosmic strings in M^4. How the GRT based picture about early cosmology differs from TGD based picture in which one has genuine conservation laws? Can one find some justification for the dominance of cosmic strings?

1. Before going to the mathematical details it must be made clear that GRT based cosmology emerges in TGD framework as QFT-GRT limit of TGD. Gauge potentials and gravitational field as deviation of metric from M^4 metric emerge as sums of corresponding induced gauge fields over different space-time sheets with 4-D space-time projection.

   In fact, in TGD inspired cosmology one assumes that cosmic expansion takes place as rapid phase transitions. This picture is suggested both by the solutions of field equations and the empirical fact that astrophysical objects do not expand in smooth manner but might do so in jerks. This leads to TGD variant expanding Earth model motivated by some strange geological findings and applied to Cambrian explosion.

2. Light-cone can be thought of as empty Robertson-Walker cosmology formally. In R-W coordinates for light-cone one has $ds^2 = da^2 - a^2(dr^2/(1+r^2) + r^2\Omega^2)$. These coordinates become singular at light-cone boundary $a = 0$ and formally the metric reduces 1-D $ds^2 = da^2$. Non-vanishing values of the ordinary Minkowski radial coordinate $r_M = ar$ requires that r $r = r_M/a$ approaches ∞. The hyperbolic angle η in $r = sinh(\eta)$ must approach to $\eta = \infty$ for $a \to 0$.

   Robertson-Walker coordinates are not suitable in TGD framework since they are singular at light-cone boundary and to see what happens it is best to use light-cone coordinates ($u = t - r_M, v = t + r_M, \theta, \phi$), where $u = 0$ corresponds to light-cone boundary and $v = 2r_M$, where r_M is radial M^4 coordinate at light-cone boundary. M^4_+ metric is $2dudv - ((u-v)^2/4)d\Omega^2$. One can use for space-time surfaces with 4-D M^4 projection these coordinates.

One can consider several descriptions.
Space-time description in TGD framework:

1. One can deduce conserved energy momentum currents in TGD framework and one can assign to the ends of space-time surface conserved four-momenta unlike in GRT. The conserved 4-momentum currents contractions $j^\alpha_A = (T^{\alpha_b eta a}\partial_\beta h^l h_{kl} j A k\sqrt{g_4}$, where j^K_k is vector field defining of isometry. T is determined by the action which is sum of volume and Kähler terms. The four-momentum in given volume is obtained by integrating momentum density over 3-surface at the boundary of CD.

2. For space-time surfaces it is easy to see that for 3-surfaces the energy-momentum currents determined by the action (Kähler action plus volume term) and therefore conserved momenta remain finite since the induced metric is invertible in the generic case. Energy momentum for a volume corresponding to a finite value of $r = r_M/a = (v-u)/2\sqrt{uv} \sim \sqrt{v/u}$ however vanishes since v must approach to zero like u and integration over v gives zero at this limit.

GRT description as cosmic string dominated cosmology:

1. The assumption that mass density in $T^{aa} = g^{aa}\rho$ of the ordinary R-W cosmology satisfies $\rho \propto 1/a^n$: $n = 4, 3, 2$ for radiation -, matter -, and cosmic string dominated cosmology. In Minkowski cosmology this would imply even for $n = 2$ that the component $T^{aa} = g^{aa}\rho$ behaves like g^{aa}/a^2. The integral of ρ over co-moving volume $\propto a^3$ would behave like a for string dominated cosmology one $\rho \propto 1/a^2$. Note that the mass defined in this manner is the best that one can achieve in GRT and would be finite form for a co-moving sphere with any finite value of r so that the mass density is singular and energy as Noether charge would diverge for finite values of M^4 radius r_M.

2. One could see the singularity as failure of GRT description at the limit light-cone boundary and being due to the wrong assumption that M^4 projections of space-time surfaces are 4-D: this in turn implies that the tota mass density diverges for infinite number of space-time sheets.

Description as gas of cosmic strings in M^4: Suppose that it make sense to speak about conserved energy momentum tensor in M^4_+ as the picture about gas of cosmic strings in M^4_+ suggests. By isometries of M^4_+ this energy momentum tensor - if suitably defined, gives rise to conserved quantities. What one obtains if one assumes that the energy momentum currents remains finite at light-cone boundary?

1. After the transition to radiation dominated cosmology in which M^4_+ projections of the space-time surfaces are 4-D and one can speak about many-sheetedness. If the number of space-time sheets becomes large as is expected to happen after transition to radiation dominance, the sum of metrics would at GRT limit give an metric for which Einstein tensor and metric gives an energy density behaving like in GRT based cosmology.

2. Could very early cosmology be modelled as a gas of cosmic strings in M^4_+? Assume that four-momentum in the model for a gas of cosmic strings in M^4_+ is finite for finite M^4 volume. Assume that energy momentum tensor in M^4_+ is $T^{uv} = kg^{uv}$: this guarantees vanishing of covariant divergence. One can also consider the possibility that the energy momentum tensor is proportional to M^4_+ metric (Einstein tensor of M^4_+ vanishes). This conforms with the assumption of string dominance in which 2 degrees of freedom of space-time surfaces correspond to either geodesic sphere of CP_2. If k is constant the divergence of energy momentum tensor vanishes.

3. The energy-momentum densities are given by $j^{Au} = kg^{uv}\partial_v m^k \sqrt{g_4}$, $\sqrt{(g_4)} = r_M^2 sin(\theta) = (u-v)^2 sin(\theta)/2$. These currents are conserved and define conserved charged for fixed M^4 sphere with radius $r_M = ar$. This volume *does not* correspond to co-moving volume with constant r appearing GRT framework. GRT and TGD pictures differ for very early times for the reasons already explained. The most important implication is that initial singularity disappears in TGD framework.

2.3 Does ZEO based cosmology predict the concentric circles?

Can one imagine signatures of ZEO cosmology analogous to those proposed by Penrose?

1. The evaporation of galactic blackholes or cosmic strings thickening the into flux tubes would generate a pulse of Hawking radiation travelling with average velocity $v \leq c$ to the active boundary of CD. One has actually $v < c$ due to interaction with matter so that the path of photon is not quite light-like. The photons would be absorbed by flux tubes and suffer time reflection in the "big" state function reduction. In statistical sense they would reflect back in time with opposite four-momentum in the "big" state function reduction. Conservation of total quantum numbers does not require that photon momentum changes sign but this is expected to be true in good approximation in statistical sense. For $v = c$ photon would return exactly to the position where it started from.

   $v < c$ however means that pulse absorbed by flux tubes and arrives after "big" state function reduction back along different route. By looking what happens during several aeons, one finds that one obtains sequences of 2-surfaces as reflection surfaces at the boundary of CD (which also increase during sequence of state function reductions). Could these spheres give rise to a sequence of concentric circles as intersection of a 3-D light-cone associated with observer with these spheres?

2. One can also consider the analog of pulses of Hawking radiation from magnetic flux tubes containing dark matter and generating the ordinary elementary particles as analog of inflation. Quasars and gamma ray bursts (GRBs) could be analogs of these processes and there is sub-pulse structure in the pulses but in time scale varying from millisecond to 100 seconds and therefore totally different order of magnitude than the age of the Universe. Could the pulses of radiation from these objects assignable to different aeons give rise to concentric circles?

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