

Does the rate of cosmic expansion oscillate?

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Abstract

H. I. Ringermacher and L. R. Mead have written a very nice article with title “Observation of discrete oscillations in a model-independent plot of cosmological scale factor versus lookback time and scalar field model”. I summarize the contents of the article and consider TGD inspired model for the findings based on the assumption that dark matter corresponds to phase with gigantic values of effective Planck constant. There is also a summary about Gaussian Mersennes, which predict correctly both cosmological, astrophysical, biological, nuclear physics, length scales and predict new important length scales in particle physics.

1 Introduction

H. I. Ringermacher and L. R. Mead have written a very nice article (<http://arxiv.org/abs/1502.06140>) with title “Observation of discrete oscillations in a model-independent plot of cosmological scale factor versus lookback time and scalar field model” [E2]. In the following I summarize the contents of the article as I understand it. After that I consider TGD inspired model for the findings based on the assumption that dark matter corresponds to phase with gigantic values of effective Planck constant. Appendix contains summary about Gaussian Mersennes which predict correctly both cosmological, astrophysical, biological, nuclear physics, length scales and predict new important length scales in particle physics.

The claim of the article is that the time derivative of the cosmic scale parameter da/dt oscillates periodically. When da/dt has minimum or maximum, the acceleration parameter d^2a/dt^2 of the Universe changes sign accelerating expansions changes to slowing down or vice versa. The authors have used several methods such as smoothing, fast Fourier transform and autocorrelation and they are reported to all give the same results. 3.5 sigma is mentioned as characterization of the reliability of finding: the probability that it finding is fluke would be smaller than .1 per cent if the observable value obey Gaussian distribution (<http://blogs.scientificamerican.com/observations/five-sigmawhats-that/>). For a layman it seems a miracle that the authors can extract from the chaotic looking data for da/dt a nice graph showing at least three minima and maxima.

Authors reports that the acceleration for the rate of cosmic expansion oscillates rather than being approximately constant. Instead of single transition redshift at which acceleration changes sign there are three in the region of redshifts studied. The period of oscillation in cosmic time t is deduced to be approximately .15 ($\simeq 1/7$) Hubbles times $T_H = 1/H_0 \simeq 1.4 \times 10^{10}$ years= 14 aeons from the nominal value of $H_0 = 68 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

The findings are explained in terms of a model of dark energy and matter. Quite generally, these models explain dark energy in terms of vacuum energy of some field. It is assumed that scalar field vacuum expectation value oscillating with frequency $f = .15H_0$ and attenuating exponentially with an attenuation coefficient $\lambda = 2.8/t(\text{now})$, where $t(\text{now})$ is the age of the Universe about $t(\text{now}) = 1.38 \times 10^{10}$ years. The mass of the scalar field would be incredibly small - about 3×10^{-32} eV. The corresponding Compton time would be 1.3×10^{10} years and very close the age of the Universe. The model is otherwise like Λ CDM model but adds this tiny effect. Hence the constantly accelerating expansion is modified with oscillating expansion slightly deviating from from during the early cosmology.

In absence of accelerating expansion redshift z would be in good approximation linear in time. Now the situation is however nonlinear and authors deduce the relationship $t = t(z)$ allowing to express a and da/dt as functions of redshift z , which in ideal cosmic expansion is given by $z = a(\text{now})/a(\text{then}) - 1$, where $a(\text{now})$ and $a(\text{then})$ are value of scale radius a now and at the moment of emission.

The model thus replaces single transition redshift with average value $z = .77$ with three transition redshifts. In fact, it has been found that Planck date differ in details from the earlier CMB data modelled rather satisfactorily in Λ CDM model.

The relative minima of da/dt were found at times $t/t(\text{now}) = 0.78, 0.63$ and 0.47 and relative maxima at times $t/t(\text{now}) = 0.87, 0.71$ and 0.56 . $\Delta t/t(\text{now}) = .15$ is clearly the period. The relative minima correspond to red-shifts of $z = 0.26, 0.51$, and 0.9 : note that the first two correspond to approximate periodicity with $\Delta z = .25$ but the third - the earliest minimum at which acceleration begins to corresponds to much larger redshift than one might expect. The relative maxima correspond to $z = 0.14, 0.3$, and 0.66 (in the maximum the acceleration becomes negative). The reported transition phase shifts have a rather wide distribution. The identified transition redshifts are reported to be near to those reported in literature. The wide distribution of transition redshifts shows how large the uncertainties concerning the beginning of the accelerated expansions are.

2 TGD based model for the findings

TGD based model relies heavily on recent TGD inspired view about cosmology and general ideas of quantum TGD, in particular the possibility of dark matter quantum coherent in astrophysical and even cosmological scales.

1. p-Adic length scale hypothesis allows to make quantitative estimates and so called Gaussian Mersennes discussed in the Appendix allow to identify fundamental length and time scales covering cosmology, astrophysics, biology, nuclear physics, and particle physics. TGD based description of dark matter as a hierarchy of phases with non-standard value of Planck constant is second new element.
 - (a) p-Adic length scale hypothesis leads to the vision that cosmic expansion is not smooth at the level of many-sheeted space-time but takes place as rather rapid phase transitions. Either the p-adic length scale or dark length scale characterized by the value of the effective Planck constant $h_{\text{eff}} = n \times h$ assignable to the dark matter changes. The identification $h_{\text{eff}} = \hbar_{\text{gr}} = GMm/v_0$ assignable to a dark energy carrying magnetic flux tube connecting masses M and m is very attractive: v_0 is a velocity parameter characterizing the system and in the model for the planetary system has same value for inner (outer) planets [K5, K3].
 - (b) For a given dark matter object no expansion would occur during the intermediate periods. For instance, it is known that solar system does not participate cosmic expansion but only comoves. I have proposed that even Earth has suffered a local variant of such a phase transition increasing its size by a factor two: Cambrian explosion in biology would relate to this transition [K2].
 - (c) Critical cosmology would describe the phase transition. This model is a long length scale description of the situation in single sheeted space-time of GRT obtained by replacing the sheets of many-sheeted space-time with a slightly curved regions of Minkowski space with gravitational and other fields determined as sums of the gravitational fields and gauge potentials for the sheets [K7]. TGD inspired cosmology suggests a one parameter model for these phase transitions [K6]. This model is also behind the TGD counterpart of inflationary cosmology identified as a phase transition from cosmic string dominated phase to that in which GRT type space-time dominates. Phase transitions modellable by critical cosmology could also explain accelerated expansion considered now as occurring in much longer length and time scales.
 - (d) At the deeper level magnetic flux tubes carrying monopole fluxes are carriers of dark energy as magnetic energy and of dark matter as large h_{eff} phases. No new scalar fields such as inflaton fields are introduced. The hierarchy of Planck constants can be reduced

to quantum criticality of TGD Universe allowing quantification in terms of a hierarchy of algebraic extensions of rationals in number theoretic formulation of TGD [K10]. The parameters characterizing string world sheets and partonic 2-surfaces serving as “space-time genes” and continuable to space-time surfaces as preferred extremals of Kähler action in strong holography belong to these algebraic extensions forming a hierarchy and inducing corresponding extensions of p-adic number fields allowing to extend real number based physics to adelic physics.

2. Zero energy ontology brings in further new elements.
 - (a) The number theoretic vision leads to the discretization of the moduli space for causal diamonds (CDs, basic element of ZEO) with second boundary fixed. Without discretization the moduli space would be hyperbolic space H^3 - cosmic time $a = \text{constant}$ section of future directed lightcone. Note that a corresponds to the scale factor $a(t)$ in TGD based cosmology. Discretization of H^3 is necessary and is obtained as a tesselation by identifying the points related by a infinite discrete sub-group H of $SL(2, C)$. The counterpart of lattice cell is H_3 coset defining hyperbolic manifold. The causal diamonds crucial for zero energy ontology have discrete wave function in this space. This suggests a lattice like structures in the sense that position of a physical system defined by the non-fixed top of corresponding CD has discrete position in the lattice defined by the action of the subgroup H . In ordinary 3-D lattices position is quantized. Now the direction of recession velocity and the the hyperbolic angle defining the redshift associated with the corresponding astrophysical objects is quantized. Note that the redshift characterized the position only if the object is co-moving.
 - (b) Also the tesselation of second light-like boundary of causal diamond (CD) defines discrete moduli space identifiable as the orbit of discrete subgroup H : this tesselation would be limiting case of that for hyperbolic 3-space. In this case the lattice like structure would be physical and realized at space-time level. The positions of partonic 2-surfaces would form lattice like structure at the light-like boundary. Biology suggests that dark flux tubes form a grid like structure analogous to coordinate grid. For instance, in TGD based model galaxies are like pearls in the necklace formed by a flux tube. The dynamics of this dark lattice like structure would make it visible itself in the behavior of the visible matter.
- There is a strong temptation to think that the dark matter can form lattice like structures at the light-like boundary of CD. And these structures would expand in stepwise manner by rapid quantum phase transitions. This because dark matter could be quantum coherent in cosmological length scales.
- (c) Adelic physics [K10] allows to consider a concrete prediction for the unit of quantized cosmic redshifts if astrophysical objects form tesselations of light-cone boundary and even H^3 in cosmic scales. The basic unit appearing in the exponent defining the Lorentz boost would depend on the algebraic extension involved and of p-adic prime defining effective p-adicity and would be $e^\eta = e^{k/np}$, $0 \leq k < np$. The hyperbolic “phase” relates by the standard formula to the redshift: $1 + z = e^\eta = e^{k/np}$. The relationship to the cosmic recession velocity $\beta = v/c$ is obtained from $\exp(\eta) = \gamma \times (1 + \beta) = \sqrt{(1 + \beta)/(1 - \beta)}$, $\gamma = 1/\sqrt{1 - \beta^2}$: $\beta = (\exp(2\eta) - 1)/(\exp(2\eta) + 1) = (\exp(2k/np) + 1)/(\exp(2k/np) - 1) \simeq k/np$. The recession velocity v is approximately quantized in multiples of $v_0 = c/np$. This formula for redshifts would hold true if cosmic expansion is the sole reason for the redshift and matter is concentrated at lattice points. The obvious question is whether the transition redshifts correspond to lattice points with constant red-shift difference in the first approximation. There indeed exist support for the quantization of redshifts [E3, E1]. As shown in [K9] [L1] the discretization at the level of moduli space of CDs could have direct connection with quantum groups describing finite measurement resolution at quantum level.
3. One cannot avoid bringing in TGD inspired theory of consciousness when one speaks about quantum phase transitions in ZEO [K8, K1].

- (a) ZEO based theory of quantum measurement defines a theory of consciousness and leads rather straightforwardly to the identification of the quantum physical correlates for the notion of self [K4, K1, K8]. These quantum phase transitions could correspond to state function reductions to the opposite boundary of CD following a sequence of reductions at fixed boundary (analog of repeated quantum measurement giving rise to Zeno effect). The reduction to opposite boundary would mean change of the arrow of time for CD in the scale considered: recall that CDs form a hierarchy and the arrow of time changes for dark matter.
- (b) Could the phase transitions changing the size scale of the lattice be this kind of phase transitions? It seems clear that if state function reductions at opposite boundary occur in cosmic scale, it must be followed rather rapidly by a phase transition bringing back the original arrow of time since otherwise the cosmology would become time reversed. Could the arrow of time associated with a larger CD force define standard arrow of time and force a rapid return to it for sub-CDs?

The following model for cosmic expansion as rapid phase transitions followed by damped oscillations suggests itself.

1. Dark matter lattice would not expand smoothly but by phase transitions in which the scale of the lattice would increase by a power of two (one cannot exclude $\sqrt{2}$ and in principle even powers of p or \sqrt{p} must be considered). This could be interpreted as an increase of p -adic length scale or of effective Planck constant by factor 2. The subgroup H defining the lattice cell might change and the standard wisdom about phase transitions suggests that symmetry breaking to subgroup occurs. Super-symplectic algebra allows infinite hierarchy of sub-algebras isomorphic to with conformal weights coming as multiples of those for the entire algebra so that one has fractality: symmetry breaking without symmetry breaking. Same symmetry appears in larger scale defined by the new value of h_{eff} .
2. During the phase transitions rapid acceleration would occur and z would be larger than predicted by the models with smooth expansion. The authors indeed find that the earliest transition redshift is unexpectedly large. These transitions would be followed by lattice oscillations inducing the oscillations of da/dt too.
3. Visible matter would comove in the background defined by dark matter and would respond to dark matter phase transitions in cosmic scale in induced dynamics with additional anomalous expansion lasting the duration of dark matter phase transition. Comoving property means for visible matter means that in the scale of CD involved visible matter does not expand during the intermediate periods. This is known to be the case for solar system.
4. As found, the claimed transition redshifts correspond to scalings of a by factor smaller 2, which suggests that they three cycles (also fourth could be included in the model of authors) do not correspond to separate phase transitions but to single phase transition followed by an oscillation as in the proposed model. Time value t assigned to the three minima and maxima of da/dt are evenly spaced in good approximation.

Number theoretical quantization for the exponents of the hyperbolic angles (analogous to phases) gives $z = \exp(k/np) - 1$, $k = 1, \dots, np - 1$ if no other sources of redshifts are present. If there are four minima within octave of a/a_0 , one must have $p = 2$ and $n = 2$: both values are very natural. In this case the linear approximation for z is not good. The kinematical redshifts for the minima would be $z \in \{.28, .65, 1.12\}$: note that the ratios of $1+z$ factors remain below 2. The reported redshifts for the minima are $z \in \{0.26, 0.51, 0.9\}$ smaller. There seems to be a contribution reducing the redshifts from their kinematical values: this contribution could come from a lattice oscillation partially compensating the comoving accelerated expansion and bringing acceleration to zero and at the same time reducing the expansion rate and thus also z .

A possible criticism of the model is the introduction of dark matter lattice replacing the scalar field of [E2] with oscillating vacuum expectation value. The observed redshift quantization could be used to defend this assumption. Quantum coherence in cosmological scales of course raises

the eyebrows of the standard physicist but the recent fashion in which wormholes are assumed to connect blackholes and give rise to quantum coherence is consistent with this picture, which can be seen as a GRT adaptation of TGD vision in which magnetic flux tubes replace wormholes and partonic 2-surfaces replaced blackhole horizons and space-time regions having Euclidian signature of induced metric serving as lines of generalized Feynman diagrams replace blackhole interiors.

3 Appendix: p-adic length scale hypothesis and Gaussian Mersennes

The proposed model does not say much about p-adic primes important in cosmology. The following arguments demonstrate as a by-product that Gaussian Mersennes define p-adic length scales having identification as fundamental length scales both in cosmology and astrophysics. The largest Gaussian Mersenne defines slightly longer time scale than the age of the Universe appearing as the parameter in the model for oscillations and this Gaussian Mersenne could explain why just this time scale appears. What is remarkable the age of the Universe would correspond to a length scale analogous to length scales fundamental in TGD inspired quantum biology and one can wonder whether this has a deeper meaning. What is also remarkable, that the p-adic Compton lengths for dark electron define the fundamental scales. Does this mean that dark electrons or their p-adically scaled down variants are important in all these scales?

p-Adic length scale hypothesis states that primes slightly below powers of two are physically preferred ones. Mersenne primes $M_n = 2^n - 1$ obviously satisfy this condition optimally. The proposal generalizes to Gaussian Mersenne primes $M_{G,n} = (1+i)^n - 1$ (<http://primes.utm.edu/glossary/xpage/GaussianMersenne.html>). It is now possible to understand preferred p-adic primes as so called ramified primes of an algebraic extension of rationals to which the parameters characterizing string world sheets and partonic 2-surfaces belong. Strong form of holography is crucial: space-time surfaces are constructible from these 2-surfaces: for p-adic variants the construction should be easy by the presence of pseudo-constants. In real sector very probably continuation is possible only in special cases. In the framework of consciousness theory the interpretation is that in this case imaginations (p-adic space-time surfaces) are realizable. Also p-adic length scale hypothesis can be understood and generalizes: primes near powers of any prime are preferred.

The definition of p-adic length scale is a convention to some degree.

1. One possible definition for L_p is as Compton length for the smallest mass possible in p-adic thermodynamics for a given prime if the first order contribution is non-vanishing.
2. Second definition is the Compton length $L_{p,e}$ for electron if it would correspond to the prime in question: in good approximation one has $L_p = \sqrt{5} \times L_{p,e}$ from p-adic mass calculations. If p-adic length scale hypothesis is assumed ($p \simeq 2^k$) one has $L_{p,e} \equiv L(k, e) = 2^{(k-127)/2} L_e$, where L_e is electron Compton length (electron mass is .5 MeV). If one is interested in Compton time $T(k, e)$, one obtains it easily from electrons Compton time .1 seconds (defining fundamental biorhythm) as $T(k, e) = 2^{(k-2*127)/2} \times .1$ seconds. I will mean with p-adic length scale $T(k, e) \simeq \sqrt{5}T(k)$ in the following.

Mersenne primes $M_n = 2^n - 1$ are as near as possible to power of two and are therefore of special interest.

1. Mersenne primes corresponding to $n \in \{2, 3, 5, 7, 13, 17, 19, 31, 61\}$ are out of reach of recent accelerators.
2. $n = 89$ characterizes weak bosons and suggests a scaled up version of hadron physics which should be seen at LHC. There are already several indications for its existence.
3. $n = 107$ corresponds to hadron physics and tau lepton.
4. $n = 127$ corresponds to electron. Mersenne primes are clearly very rare and characterize many elementary particle physics as well as hadrons and weak bosons. The largest Mersenne prime which does not define completely super-astrophysical p-adic length scale is M_{127} associated with electron.

Gaussian Mersennes (complex primes for complex integers) are much more abundant and in the following I demonstrate that corresponding p-adic time scales might seem to define fundamental length scales of cosmology, astrophysics, biology, nuclear physics, and elementary physics. I have not previously checked the possible relevance of Gaussian Mersennes for cosmology and for the physics beyond standard model above LHC energies: there are as many as 10 Gaussian Mersennes besides 9 Mersennes above LHC energy scale suggesting a lot of new physics in sharp contrast with the GUT dogma that nothing interesting happens above weak boson scale- perhaps copies of hadron physics or weak interaction physics. The list of Gaussian Mersennes is following.

1. $n \in \{2, 3, 5, 7, 11, 19, 29, 47, 73\}$ correspond to energies not accessible at LHC. $n = 79$ might define new copy of hadron physics above TeV range -something which I have not considered seriously before. The scaled variants of pion and proton masses (M_{107} hadron physics) are about 2.2 TeV and 16 TeV. Is it visible at LHC is a question mark to me.
2. $n = 113$ corresponds to nuclear physics. Gaussian Mersenne property and the fact that Gaussian Mersennes seem to be highly relevant for life at cell nucleus length scales inspires the question whether $n = 113$ could give rise to something analogous to life and genetic code. I have indeed proposed realization of genetic code and analogs of DNA, RNA, amino-acids and tRNA in terms of dark nucleon states.
3. $n = 151, 157, 163, 167$ define 4 biologically important scales between cell membrane thickness and cell nucleus size of $2.5 \mu\text{m}$. This range contains the length scales relevant for DNA and its coiling.
4. $n = 239, 241$ define two scales $L(e, 239) = 1.96 \times 10^3$ km and $L(e, 241) = 3.93 \times 10^3$ km differing by factor 2. Earth radius is 6.3×10^3 km, outer core has radius 3494 km rather near to $L(2, 241)$ and inner core radius 1220 km, which is smaller than 1960 km but has same order of magnitude. What is important that Earth reveals the two-core structure suggested by Gaussian Mersennes.
5. $n = 283$: $L(283) = .8 \times 10^{10}$ km defines the size scale of a typical star system. The diameter of the solar system is about $d = .9 \times 10^{10}$ km.
6. $n = 353$: $L(353, e) = 2.1$ Mly, which is the size scale of galaxies. Milky Way has diameter about .9 Mly.
7. $n = 367$ defines size scale $L(267, e) = 2.8 \times 10^8$ ly, which is the scale of big voids.
8. $n = 379$: The time scale $T(379, e) = 1.79 \times 10^{10}$ years is slightly longer than the recently accepted age of the Universe about $T = 1.38 \times 10^{10}$ years and the nominal value of Hubble time $1/H = 1.4 \times 10^{10}$ years. The age of the Universe measured using cosmological scale parameter $a(t)$ is equal to the light-cone proper time for the light-cone assignable to the causal diamond is shorter than t .

For me these observations are shocking and suggest that number theory is visible in the structure of entire cosmos. Standard skeptic of course labels all this as numerology. Only understood fact is fact. TGD indeed allows to understand these facts.

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