Cosmology in crisis

M. Pitkänen
Email: matpitka6@gmail.com.
http://tgdtheory.com/.

November 13, 2019

Abstract

Standard cosmology is in crisis. There are a lot of anomalies but two of them have received special attention recently. The most recent anomaly is due to the findings that the so called lensing amplitude in CMB is larger than ΛCDM predicts. This suggest that the density of the Universe is 5 per cent higher than the critical density so that Universe should closed rather than flat and infinite. Second anomaly is old: depending on measurement method one obtains two values for the Hubble constant differing remarkably. The debate about this has continued for decades and continues still. In this article the two above mentioned problems regarded as crises are discussed in terms of TGD view about space-time.

Contents

1 Introduction

Standard cosmology is in crisis. There are a lot of anomalies but two of them have received special attention recently. The most recent anomaly is due to the findings that the so called lensing amplitude in CMB is larger than ΛCDM predicts [E1]. This suggest that the density of the Universe is 5 per cent higher than the critical density so that Universe should closed rather than flat and infinite. Second anomaly is old: depending on measurement method one obtains two values for the Hubble constant differing remarkably. The debate about this has continued for decades and continues still.

These anomalies and many other suggest that that something is wrong with - not only the assumptions of GRT based cosmology - but with Einsteinian space-time. TGD indeed predicts new view about space-time. Space-time at fundamental level is identified as 4-D surface in 8-D $M^4 \times CP_2$. The resulting many-sheeted space-time is locally extremely simple but has non-trivial topology in all scales. The M^4 projection of space-time regions can have dimension $D \leq 4$. For $D = 4$ one can speak of Einsteinian space-time. Non-Einsteinian configurations such as CP_2 type extremals $D = 1$ representing elementary particles and cosmic strings with$D = 2$ play central role in TGD Universe in all scales. For $D < 4$ the dimension of projection is topologically unstable and cosmic strings thicken to flux tubes. GRT space-time is obtained by taking into account only the

Einsteinian spacetime surfaces at QFT-GRT limit but one expects that this is not enough: cosmic strings bring in new effects not present in typical GRT cosmology.

In this article the two above mentioned problems classified as crises are discussed in terms of TGD view about space-time.

2 Is 3-space closed or flat and infinite?

ΛCMD model (see http://tinyurl.com/z8z8ulu) provides the standard model for cosmology model assumes flat 3-space cold dark matter realized in terms of dark matter halos at galactic level. Cosmological constant Λ parameterizes dark energy density. The gives a rather satisfactory description of the CMB data in terms of 6 parameter but there are however some anomalies. There deviations from the predictions from the actual CMB data. The problems related to the notions of dark matter and energy itself are at deeper levels.

Now a new problem - even crisis - has emerged (I have the feeling that it has been always in crisis). There is evidence that 3-space is actually closed rather than flat and infinite! But 3-space cannot be both simultaneously.

2.1 Findings

Alessandro Melchiorri of Sapienza University of Rome Eleonora di Valentino of the University of Manchester and Joseph Silk, principally of the University of Oxford, published in Nature Astronomy a paper "*Planck evidence for a closed Universe and a possible crisis for cosmology*" [E1] (see http://tinyurl.com/y5q55ds3). Here is the abstract of the article.

The recent Planck Legacy 2018 release has confirmed the presence of an enhanced lensing amplitude in cosmic microwave background power spectra compared with that predicted in the standard Λ cold dark matter model, where Λ is the cosmological constant.

A closed Universe can provide a physical explanation for this effect, with the Planck cosmic microwave background spectra now preferring a positive curvature at more than the 99 per cent confidence level.

Here, we further investigate the evidence for a closed Universe from Planck, showing that positive curvature naturally explains the anomalous lensing amplitude, and demonstrating that it also removes a well-known tension in the Planck dataset concerning the values of cosmological parameters derived at different angular scales. We show that since the Planck power spectra prefer a closed Universe, discordances higher than generally estimated arise for most of the local cosmological observables, including baryon acoustic oscillations. The assumption of a flat Universe could therefore mask a cosmological crisis where disparate observed properties of the Universe appear to be mutually inconsistent. Future measurements are needed to clarify whether the observed discordances are due to undetected systematics, or to new physics or simply are a statistical fluctuation.

A lensing amplitude 5 per cent larger than expected is observed. Concretely this means following.

1. Gravitational lensing (see http://tinyurl.com/c3n6b8g)) is essentially scattering of the incoming light in the gravitational field of matter between the detector an sources so that for a single object between the source the light seems to becoming from a circular object rather than point like object.

2. The light of CMB entering detector has experienced large number of lensings and the images of various features in the data become blurred. The larger the lensing, the more blurred the object image. Lensing amplitude is proportional to the curvature of 3-space and if the curvature vanishes as in flat cosmology, lensing amplitude should be very small and due to fluctuations. There should be for other reasons.

3. ΛCDM predicts flat 3-space so that the observed lensing is anomaly if indeed real effect. The obvious explanation would be that the density of matter is about 5 per cent higher than the model predicts. The density would become overcritical and the infinite flat 3-space would close to sphere. This would be a dramatic change in the topology of 3-space.

As the abstract tells, positive curvature would also remove the well-known tension in the Planck dataset concerning the values of cosmological parameters derived at different angular scales.

There are however objections. For instance, inflation theory favours infinite 3-space. There is also second manner to deduce 3-curvature. Lensing reconstruction measures correlations from sets of four points in the sky to deduce 3-curvature. The results are in accordance with flatness.

Various empirical inputs force flat 3-space so that one cannot just add to ΛCDM the curvature as 7:th parameter. For instance, it would very difficult to understand how this modification could be consistent with inflation theory involving flat expanding Universe. Therefore one can say that cosmology is in crisis.

2.2 What says TGD?

Something new is needed. Hyperbolic or flat Universe seems to be a natural assumption in TGD framework assuming that at fundamental level space-times are surfaces in $M^4 \times CP_2$.

1. General Relativity emerges as a long length scale approximation in which space-time surfaces are assumed to be Einsteinian in long scale, that is having 4-D M^4 projection. There are also non-Einsteinian space-time surfaces. CP_2 type extremals with 1-D light geodesic as M^4 projection, and string like objects with 2-D M^4 projection.

2. Cosmic strings are basic entities of the primordial cosmology in TGD Universe and have 2-D M^4 projection as string world sheets: there is no Einsteinian space-time and it emerges during the TGD analog of the inflationary period [K1, K4]. Cosmic strings are unstable against thickening of the $M4$ projection of cosmic strings so that they tend to thicken to flux tubes. Cosmic strings and flux tubes are present also during the Einsteinian era. One can speak of topological condensation of cosmic strings to space-time surface. In GRT based cosmology these objects have no counterpart.

   Cosmic strings appear in two varieties depending on whether the quantizes magnetic flux associated with their closed cross section is monopole flux or not (vanishes). What is important that monopole fluxes require no currents, which solves several problems of cosmology and astrophysics. One example is the presence of magnetic fields in cosmic length scales, stability of the Earth's magnetic field [L1] and the present strange findings about the magnetic field of Mars [L9].

3. The model for the formation of various astrophysical objects [L7, L11, L12] relies on the thickening of cosmic string portions to monopole flux tubes. One must therefore include them. In accordance with the notion of many-sheeted space-time, cosmology must be replaced with a fractal hierarchy of cosmologies with length scale dependent parameters such as cosmological constant [L2].

   Remark: String world sheets appear also as singularities of space-time surfaces as minimal surfaces appearing as extremals of also 4-D Kähler action obtained as a dimensional reduction of the twistor lift of 4-D Kähler action. These strings are like edges of 3-space at which tangent space-time dimension of space-time surface is 2 instead of 4.

4. Cosmic strings carry dark energy and dark matter. Dark energy is sum of magnetic and volume contributions. The latter is proportional to cosmological constant Λ, which depends on the size scale of the space-time sheets and comes in some negative powers of 2 corresponding to preferred p-adic length scales. Λ_{CDM} would correspond to length scale for space-time sheets of order recent size of cosmos.

In this framework the most recent crisis of cosmology would reflect the failure of the Einsteinian space-time concept basically due to the existence of cosmic strings and other objects with lower-D projection.

The observed too large lensing amplitude is intuitively easy to understand in terms of cosmic strings. The incoming CMB photon would express additional scattering from long cosmic strings along its route. Second manner to deduce the curvature is by measuring correlations from sets of 4 points in the sky. The correlations should not change if TGD is correct. I do do not understand enough these correlations to tell whether the presence of cosmic strings and flux tubes affect the correlations or not.

The conceptual and technical challenge is to understand how two treat cosmic strings in the QFT-GRT limit of TGD based fractal cosmology.

1. For space-time surfaces with 4-D M^4 projection the GRT space-time is obtained as 4-D piece of M^4 with gauge potentials and the deviation of metric from flat M^4 metric as a sum of those for space-time sheets. One actually obtains a length scale hierarchy of space-times assignable to causal diamonds (CDs) and standard cosmology should correspond to the limit of CD size, which is about the size of the recent cosmology. CMB data indeed suggest length scale dependence of CMB parameters.

2. At every step in hierarchy 3-space is finite corresponding to the radius of CD at give value of Minkowski time. The actual 3-surfaces are always closed and can be though of as pairs of 3-surfaces with boundary at boundary of CD glued together along their boundaries. Covering of flat 3-space would be in question. Could this somehow relate to why closed Universe seems to work in some respects?

   The hierarchy brings in new elements such as hierarchy of cosmological constants with a concrete interpretation discussed elsewhere.

3. But what should one do with the cosmic strings and flux tubes? The addition of them as singular string world sheets in space-time carrying concentrated a string world sheet is one possibility which comes into mind. GRT based cosmology relies on point-like objects and infinitely long cosmic strings are not point-like objects in any scale. A more plausible approach would be in terms of tensor nets with cosmic strings and flux tubes defining the connections between the nodes of the net. The identification of dark matter as $h_{eff} = n \times h_0$ phases of ordinary matter would make possible quantum coherence in arbitrarily long length scales. Fractal tensor net would be genuinely quantal object in all scales, and provide very different view about the role of quantum dynamics in cosmology and astrophysics.

3 The problem of two Hubble constants

I received a link to a popular article relating to the two values of Hubble constant (see `http://tinyurl.com/yxgvsaam`). The popular article states that the expansion is 9 per cent faster than expected. This problem is old and earlier and has been seen discrepancy: measurement suggest two different values of Hubble constant. The article suggests that the bigger value is now accepted as the correct value. Hype warning is in order. The refusal to accept the possibility of two different values might mean only the continuation of the long lasting fruitless debate. It is better two try to explain why two different values are obtained.

I have considered the problem of two value of cosmological constant already earlier in the framework provided by many-sheeted space-time [K4]. In the sequel the puzzle of two Hubble constants is discussed applying the recent view about cosmological constant. What is new that twistor lift of TGD [L2] predicts that cosmological constant is length scale dependent and that cosmological expansion consists of jerks involving accelerated periods followed by a phase transition changing reducing cosmological constant by a negative power of two and and inducing the transformation of the magnetic energy of monopole flux tubes to ordinary matter.

Monopole flux tubes have become a central element of TGD inspired cosmology and astrophysics and the natural question is whether length scale dependent cosmological constant could solve the Hubble discrepancy? It seems that the higher value of cosmological constant corresponds to a smaller scale for observations: this could explain the discrepancy. The model requires a more detailed consideration of what it it is to be a standard candle. In many-sheeted space-time of TGD also the environment of the standard candle identified as monopole flux tube matters.

For distant standard candles the environment defined by the flux tube is younger than for nearby ones. The thickening associated with the ageing of the flux tubes involving the decay of magnetic energy to ordinary matter. The reduction of magnetic energy density in turn increases the value of the metric component $\sqrt{g_{aa}}$ in the natural space-time coordinates provided by the Robertson-Walker coordinates of the light-cone (a corresponds to the proper time coordinate of the light-cone). This can give rise to the increase of the Hubble constant $H = 1/\sqrt{g_{aa}a}$ explaining why the nearby flux tubes correspond to a larger value Hubble constant. Therefore monopole magnetic flux tubes could explain also the Hubble constant discrepancy.

The many-sheeted space-time suggests a possible solution to the Hubble constant discrepancy.

1. The first TGD based explanation coming into mind is based on many-sheeted space-time that I proposed decades ago. The value of Hubble constant depends on the metric of the space-time sheet the the p-adic size scale assignable to the space-time sheet. Could the measured values of Hubble constant which differ by 9 per cent correspond to different space-time sheets having slightly different Hubble constants. p-Adic length scales come as half octaves and different p-adic lengths scales would suggest a larger difference. For instance, there is evidence that the gamma rays and neutrinos from supernova SN1987A propagated with several velocities [K2] and the explanation could be the same.

2. Could length scale dependent cosmological constant assignable to the space-time surfaces solve the problem? Could it lead to length scale dependent Hubble constant H explaining the 9 per cent discrepancy as reflecting different values of H at long and short distances or equivalently at different values of cosmological time?

In the sequel the latter option - actually a more precise formulation of the first one - is considered. An essential element of the model is the notion of length scale dependent cosmological constant predicted by the twistor lift of TGD and the phase transitions reducing the value of Λ followed by the thickening of the flux tubes induced by the decay of the magnetic energy to ordinary matter. This would lead to the increase of the Hubble constant associated with the flux tube.

3.1 The notion of length scale dependent cosmological constant

TGD predicts that cosmological constant Λ characterizing space-time sheets is length scale dependent and depends on p-adic length scale. Furthermore, expansion would be fractal and occur in jerks. This is the picture that twistor lift of TGD leads to [L2].

Quite generally, cosmological constant defines itself a length scale $R = 1/\Lambda^{1/2}$. $r = (8\pi)^{1/4}\sqrt{Rl_P}$ - essentially the geometric mean of cosmological and Planck length - defines second much shorter length scale r. The density of dark energy assignable to flux tubes in TGD framework is given as $\rho = 1/r^4$.

In TGD framework these scales corresponds two p-adic length scales coming as half octaves. This predicts a discrete spectrum for the length scale dependent cosmological constant Λ [L2]. For instance, one can assign to ..., galaxies, stars, planets, etc... a value of cosmological constant. This makes sense in many-sheeted space-time but not in standard cosmology.

Cosmic expansion is replaced with a sequence of fast jerks reducing the value of cosmological constant by some power of 2 so that the size of the system increases correspondingly. The jerk involves a phase transition reducing Λ by some negative power of 2 inducing an accelerating period during which flux tube thickness increases and magnetic energy transforms to ordinary matter. Thickening however increases volume energy so that the expansion eventually halts. Also the opposite process could occur and could correspond to a "big" state function reduction (BSFR) in which the arrow of time changes.

An interesting question is whether the formation of neutron stars and super-novas could involve BSFR so that these collapse phenomena would be kind of local Big Bangs but in opposite time direction. One can also ask whether blackhole evaporation could have as TGD analog BSFR meaning return to original time direction by a local Big Bang. TGD analogs of blackholes are discussed in [L7].

Consider now some representative examples to see whether this picture can be connected to empirical reality.

1. Cosmological constant in the length scale of recent cosmology corresponds to $R \sim 10^{26}$ m (see `http://tinyurl.com/k4bwlzu`). The corresponding shorter scale $r = (8\pi)^{1/4}\sqrt{Rl_P}$ is identified essentially as the geometric mean of R and Planck length l_P and equals to $r \sim 4 \times 10^{-4}$ m: the size scale of large neuron. This is very probably not an accident: this scale would correspond to the thickness of monopole flux tubes.

2. If the large scale R is solar radius about 7×10^8 m, the short scale $r\simeq 10^{12}$ m is about electron Compton length, which corresponds to p-adic length scale $L(127)$ assignable to Mersenne prime $M_{127}=2^{127}-1$. This is also the size of dark proton explaining dark fusion deduced from Holmlid's findings [L3, L4]: this requires $h_{eff}\sim 2^{12}$!

   Remark: Dark proton sequences could be neutralized by a sequence of ordinary electrons locally. This could give rise to analogs of atoms with electrons being very densely packed along the flux tube.

   The prediction of the TGD based model explaining the 10 year old puzzle related to the fact that nuclear abundances in solar interior are larger than outside [L11] (see `http://tinyurl.com/y38m54ud`) assumes that nuclear reactions in Sun occur through intermediate states which are dark nuclei. Hot fusion in the Sun would thus involve the same mechanism as "cold fusion". The view about cosmological constant and TGD view about nuclear fusion lead to the same prediction.

3. If the short scale is p-adic length $L(113)$ assignable to Gaussian Mersenne $M_{G,113}=(1+i)^{113}-1$ defining nuclear size scale of $r\sim 10^{-14}$ m, one has $R\sim 10$ km, the radius of a typical neutron star (see `http://tinyurl.com/y5ukv2wt`) having a typical mass of 1.4 solar masses.

   A possible interpretation is as a minimum length of a flux tube containing sequence of nucleons or nuclei and giving rise to a tangle. Neutron would take volume of about nuclear size - size of the magnetic body of neutron? Could supernova explosions be regarded as phase transitions scaling the stellar Λ by a power of 2 by making it larger and reducing dramatically the radius of the star?

4. Short scale $r\sim 10^{-15}$ m corresponding to proton Compton length gives R about 100 m. Could this scale correspond to quark star (see `http://tinyurl.com/y3n78tjs`)? The known candidates for quark stars are smaller than neutron stars but have considerably larger radius measured in few kilometers. Weak length scale would give large radius of about 1 cm. The thickness of flux tube would be electroweak length scale.

3.2 Accelerated expansion in standard cosmology

To be contact with basic numbers consider first the accelerated cosmic expansion in standard model.

1. Hubble constant is defined as the parameter

$$H^2=(\frac{\dot{a}}{a})^2 \quad . \tag{3.1}$$

   Here the shorthand $\dot{a}I=da/dt$ has been used. TGD inspired cosmology one can use Robertson-Walker coordinates as natural space-time coordinates without assuming the symmetries of Robertson-Walker cosmologies, and a corresponds to the light-cone proper time. Time coordinate t corresponds to proper time coordinate of space-time surface and one has $dt^2=g_{aa}da^2$ so that one has $dt/da=\sqrt{g_{aa}}$. Therefore one can also write

$$H^2=\frac{1}{g_{aa}a^2} \quad . \tag{3.2}$$

   In the simplified model redshift z relates to the scale factor via the formula

$$\frac{a(t)}{a(t_{now})}=\frac{f_{obs}}{f_{emit}}=\frac{1}{1+z} \quad . \tag{3.3}$$

   Here t corresponds to the value of cosmic proper time when the radiation was emitted. Accelerated expansion means that the objects are farther than they would be if the Hubble constant had had its present value all the time.

2. Friedmann equation states that the square H^2 of Hubble constant (see `http://tinyurl.com/o8l9oro`) can be written as a sum of 4 contributions.

$$H^2 = \frac{8\pi G}{3}(\rho_m + \rho_r) - \frac{k}{a^2} + \frac{\Lambda}{3}) \ . \tag{3.4}$$

   The first term is proportional to mass density ρ_m of matter and second term to the mass density ρ_r of radiation. Second ter is curvature contribution depending on the parameter $k = -1, 0, 1$ characterizing the 3-curvature of 3-space. For hyperbolic cosmology expanding forever one has k=-1. Curvature radius a corresponds in TGD to the light-cone proper time coordinate. The third term corresponds to dark energy and cosmological constant. It is positive since the expansion is accelerated. This observation was fatal for superstring theory.

3. One can write the expression of Hubble constant also in the form (see `http://tinyurl.com/ycv2t7w6`)

$$H^2 = H_0^2(\Omega_k a^{-2} + \Omega_m a^{-3} + \Omega_r a^{-4} + \Omega_{DE} a^{-3(1+w)}) \ . \tag{3.5}$$

   H_0 corresponds to Hubble constant for critical mass density and various terms correspond to curvature, matter, radiation and vacuum energy. Experimentally the parameter w characterizes the dark energy density. For $w = -1$ one has cosmological constant, which in TGD would correspond to 3-surfaces very large in all dimensions. For $w = -1/3$ one has $1/a^2$ behavior and ideal cosmic strings and acceleration parameter vanishes in this case. The real situation in TGD is between these two since cosmic strings are thickened to flux tubes.

4. The acceleration equation reads is counterpart of Newton's equation

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + 3P) \ . \tag{3.6}$$

   The pressure term is negative for the accelerated expansion and it is difficult to assign it to ordinary particles. In TGD framework the tension of cosmic strings thickened to flux tube and containing magnetic and volume contribution to energy momentum tensor would give rise to effective negative pressured term.

5. If one assumes that pressure relates to the density of energy as

$$P = w\rho \ . \tag{3.7}$$

   one obtains the parameterization given for Hubble constant in terms of w. I am not sure whether this is the most general parameterization of pressure. For $w = -1$ one has Λ_{CDM} model with constant density of dark energy. This corresponds in TGD to 3-surfaces which are large in all directions. $w = -1/3$ corresponds to cosmic strings and cosmic strings thickened to flux tubes correspond to $-1 < w < -1/3$ giving rise to accelerated expansion during the period when cosmological constant associated with volume actions remains constant. The period ends when a phase transition reducing its value by a negative power of 2 takes place. This gives to jerk-wise cosmological expansion, which occurs in all scales.

6. The technical definition for the accelerate expansion is by the following equation

$$\frac{dH}{dt} = -H^2(1 + q) \ . \tag{3.8}$$

   q is known as deceleration parameter. For $q > -1$ H increases with time. Observations suggest $q = -.55$ so that one has accelerating expansion with $d^a/dt^2 > 0$ but with decreasing H.

3.3 Accelerated expansion in TGD framework

Consider first the TGD based model for the accelerated expansion.

1. TGD predicts length scale dependent cosmological constant at the level of space-time as the coefficient of the volume term of the action obtained by dimensional reduction from the Kähler action for twistor lift.

   The first thing to notice is that this cosmological constant need not directly relate to the cosmological constant of QFT limit expect when the space-time surfaces have large dimensions in all directions. For string like objects only one dimension is large and in this case the volume energy is proportional to the length rather than volume. In the idealization that string like objects are infinitely thin the energy of string phase is proportional to $1/a^2$ as function of cosmic time rather than constant as for cosmological constant in GRT. This formula expresses the fact that the amount of string inside comoving volume is proportional to a.

2. There is however a sequence of phases transition reducing the cosmological constant to which volume energy of space-time surface is proportional to. The phase transitions induce accelerated expansion (due to accelerated thickening of monopole flux tubes) as their magnetic energy transforms to ordinary matter [L2] (see `http://tinyurl.com/y2h9wr3`). Eventually the increase of volume energy stops this accelerated expansion. One can argue that (or at least ask whether) this fastens the expansion rate temporarily. Inflation and the recent accelerated expansion would be examples of this kind jerks replacing smooth cosmological expansion in TGD Universe. These jerks occur in all scale: even in scale of Earth [L6] (see `http://tinyurl.com/yc4rgkco`).

3. Since cosmological constant and thus string tension behaves like $1/a^2$ in average sense, the energy density of strings decreases as $1/a^3$ in average sense and strings correspond to comoving matter in this sense. Hence the occurrence of the phase transitions reducing the value of Λ allow avoid the big rip predicted by the standard model.

4. During a period with given value of space-time cosmological constant the situation is between string dominated cosmology and that involving cosmological constant since flux tubes are between cosmic strings and very thick cosmic strings corresponding to cosmological constant. Therefore one expects that the parameter w characterizing acceleration expansion is between the values $w = -1/3$ corresponding to cosmology dominated by ideal strings with no acceleration and $w = -1$ corresponding to cosmological constant.

   It is not quite clear to me that the decay of magnetic energy of flux tubes to ordinary matter is responsible for accelerated expansion although by the conservation of the monopole flux it associated with the thickening of strings.

Remark: In zero energy ontology (ZEO) the TGD counterpart of "big" (ordinary) state function reduction (BSFR) changes the arrow of time whereas "small" state function reductions (SSFRs) serving as TGD counterparts of weak measurements preserve the arrow. The strange findings of Minev et al support the change of the arrow of time in BSFRs in atomic systems [L8]. The causal anomalies associated with earthquakes and volcanic eruptions suggest that even these events can correspond to BSFRs in TGD Universe [L10].

Could the formation of TGD counterparts of blackhole be BSFR and correspond to a transformation of dark energy of the thickening cosmic string to ordinary matter but in reverse direction of time [L7]? Could the formation of galaxies and perhaps even stars and planets have interpretation as a formation of white-hole - blackhole in opposite time direction involving a transformations of the dark energy of cosmic string to ordinary matter [L11]?

Could BSFRs take place even in cosmological scales [L5]? Could the phase transitions reducing the value of length scale dependent Λ be BSFRs? Thermodynamics favours the decrease of Λ, which suggests that the arrow of time does not change and SSFR is in question. If Λ increased, the arrow time would change and the process could be actually BSFR producing a cosmology with opposite arrow of time.

3.4 Could one understand the two values of Hubble constant in TGD Universe?

Flux tubes are the new element brought by TGD to cosmology, and it would not be surprising if they were essential for the understanding of the Hubble constant discrepancy. A valuable hint comes from the observation that different values of Hubble constant seem to correspond to measurements carried out in different scales: this is due to different methods to determine H from redshift - and distance data.

1. The value of Λ assignable to space-time sheets is expected to come as negative powers of 2. It is not plausible that this could explain the two different values of H. Dark energy density is estimated to be 68 per cent of the total so that this term is the largest and the reduction of this term in the formula for H^2 by factor of say 1/4 is expected to have much larger effect on H than 9 per cent. The value of Λ for space-time surface must be same for the measurements giving different value of H as already noticed.

2. From the formula $H^2 = 1/g_{aa}a^2$ one finds that the value of g_{aa} at recent time as predicted from that in distant past is larger than predicted. The positive value of $\ddot{a}$ implies that $\dot{a} = 1/\sqrt{g_{aa}}$ has increased and objects are at larger distance than they would be in absence of accelerated expansion. The idealization $H = constant$ making sense at short distances to the source corresponds to $g_{aa} \propto 1/a$ predicting $a \propto exp(t)$. The value of g_{aa} assignable to the distant objects seems to be larger than $g_{aa} \propto 1/a$ would predict. g_{aa} decreases faster than constant H predicts.

3. What does standard candle property mean in TGD framework? Standard candles as astrophysical objects should be identical, in particular they should have same age. In many-sheeted space-time there are however additional factors involved.

   Option I: Standard candle (or rather the emitters of standard candle) has environment. Let us assume that it corresponds to a flux tube. At the moment of emission this flux tube is older for nearby objects than for distant ones.

   Option II: Radiation propagates along flux tubes connecting observer and source region. Suppose that one can model it as massless extremal associated with a flux tube. For nearby sources these flux are younger than for distant sources. If these flux tubes are responsible for the effect, it is opposite to that for Option I.

4. With standard arrow of time for flux tubes, the flux tubes should thicken by the transformation of magnetic energy to ordinary matter. The loss of magnetic energy should decrease g_{aa} faster than $1/a$. The longer the flux tube, the larger the decrease of g_{aa} would be since the decrease of the energy of the flux tube increases g_{aa}. H would be smaller for older flux tubes.

5. Scale dependence means that nearby standard candles correspond to a larger value of H. For Option I, H is indeed larger for nearby sources than distant ones. For Option II H is smaller for nearby sources than distant ones, which is obviously wrong. Option II can work only if the arrow of time is non-standard for the flux tubes along which radiation propagates.

To sum up, in TGD Universe also flux tubes serving as links of the cosmic network are essential besides source and receiver and the length and thus age of the flux tube would be essential for the explanation of Hubble constant discrepancy.

REFERENCES

Cosmology and Astro-Physics

[E1] Silk J Di Valentino E, Melchiorri A. Planck evidence for a closed Universe and a possible crisis for cosmology, 2019.

Books related to TGD

[K1] Pitkänen M. TGD and Cosmology. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdclass.html#cosmo, 2006.

[K2] Pitkänen M. TGD and Potential Anomalies of GRT. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdclass.html#granomalies, 2013.

[K3] Pitkänen M. About twistor lift of TGD? In *Towards M-Matrix*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdquantum.html#hgrtwistor, 2016.

[K4] Pitkänen M. More about TGD Inspired Cosmology. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdclass.html#cosmomore, 2016.

Articles about TGD

[L1] Pitkänen M. Maintenance problem for Earth's magnetic field. Available at: http://tgdtheory.fi/public_html/articles/Bmaintenance.pdf, 2015.

[L2] Pitkänen M. How the hierarchy of Planck constants might relate to the almost vacuum degeneracy for twistor lift of TGD? Available at: http://tgdtheory.fi/public_html/articles/hgrtwistor.pdf, 2016.

[L3] Pitkänen M. Strong support for TGD based model of cold fusion from the recent article of Holmlid and Kotzias. Available at: http://tgdtheory.fi/public_html/articles/holmilidnew.pdf, 2016.

[L4] Pitkänen M. Cold fusion, low energy nuclear reactions, or dark nuclear synthesis? Available at: http://tgdtheory.fi/public_html/articles/krivit.pdf, 2017.

[L5] Pitkänen M. Conformal cyclic cosmology of Penrose and zero energy ontology based cosmology. Available at: http://tgdtheory.fi/public_html/articles/ccctgd.pdf, 2018.

[L6] Pitkänen M. Expanding Earth Model and Pre-Cambrian Evolution of Continents, Climate, and Life. Available at: http://tgdtheory.fi/public_html/articles/expearth.pdf, 2018.

[L7] Pitkänen M. TGD view about quasars? Available at: http://tgdtheory.fi/public_html/articles/meco.pdf, 2018.

[L8] Pitkänen M. Copenhagen interpretation dead: long live ZEO based quantum measurement theory! Available at: http://tgdtheory.fi/public_html/articles/Bohrdead.pdf, 2019.

[L9] Pitkänen M. Could Mars have intra-planetary life? Available at: http://tgdtheory.fi/public_html/articles/Mars.pdf, 2019.

[L10] Pitkänen M. Earhquakes and volcanic eruptions as macroscopic quantum jumps in zero energy ontology. Available at: http://tgdtheory.fi/public_html/articles/earthquakes.pdf, 2019.

[L11] Pitkänen M. Solar Metallicity Problem from TGD Perspective. Available at: http://tgdtheory.fi/public_html/articles/darkcore.pdf, 2019.

[L12] Pitkänen M. Solar Surprise. Available at: http://tgdtheory.fi/public_html/articles/solarsycle.pdf, 2019.