Is inflation theory simply wrong?

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Abstract

This article is motivated by the talk about inflation by Steinhardt, who was one of the founders of inflation theory. Steinhardt concludes that inflation is simply wrong. He discusses three kind of flexibilities of inflationary theory, which destroy its ability to predict and makes it non-falsifiable and therefore pseudoscience. In this article these arguments are discussed from TGD point of view.

1 Introduction

I listened a very nice (see http://vms.fnal.gov/asset/detail?recid=1944338) about inflation by Steinhardt, who was one of the founders of inflation theory and certainly knows what he talks. Steinhardt concludes that inflation is simply wrong. He discusses three kind of flexibilities of inflationary theory, which destroy its ability to predict and makes it non-falsifiable and therefore pseudoscience.

Basically cosmologists want to understand the extreme simplicity of cosmology. Also particle physics has turned to be extremely simple whereas theories have during last 4 decades become so complex that they cannot predict anything.

1. CMB temperature is essentially constant. This looks like a miracle. The constant cosmic temperature is simply impossible due to the finite horizon size in typical cosmology making impossible classical communications between distant points so that temperature equalization cannot take place.

2. One must also understand the almost flatness of 3-space: the value of curvature scalar is very near to zero.

Inflation theories were proposed as a solution of these problems.

The great vision of inflationists is that these features of the universe result during an exponentially fast expansion of cosmos - inflationary period - analogous to super-cooling. This expansion would smooth out all inhomogenities and an-isotropies of quantum fluctuation and yield almost flat universe with almost constant temperature with relative fluctuations of temperature of order 10^{-5}.

The key ingredient of recent inflation theories is a scalar field known as inflaton field (actually several of them are needed). There are many variants of inflationary theory (see https://ned.ipac.caltech.edu/level5/Watson/Watson5_3.html).

Inflaton models are characterized by the potential function $V(\Phi)$ of the inflaton field Φ analogous to potential function used in classical mechanics. During the fast expansion $V(\Phi)$ would vary very slowly as a function of the vacuum expectation value of Φ . Super cooling would mean that Φ does not decay to particles during the expansion period.

1. In "old inflation" model cosmos was trapped in a false minimum of energy during expansion and by quantum tunneling ended up to true minimum. The liberated energy decayed to particles and reheated the Universe. No inflaton field was introduced yet. This approach however led to difficulties.

2. In "new inflation" model the effective potential $V_{eff}(\Phi, T)$ of inflaton field depending on temperature was introduced. It would have no minimum above critical temperature and super-cooling cosmos would roll down the potential hill with a very small slope. At critical temperature the potential would change qualitatively: a minimum would emerge at critical temperature and the inflaton field fall to the minimum and decay to particles and causes reheating. This is highly analogous to Higgs mechanism emerging as the temperature reduces below that defined by electroweak mass scale.

3. In "chaotic inflation" model there is no phase transition and the inflaton field rolls down to true vacuum, where it couples to other matter fields and decays to particles. Here it is essential that the expansion slows down so that particles have time to transform to ordinary particles. Universe is reheated.

2 Objections of Steinhardt against inflation

Consider now the objections of Steinhardt against inflation. As non-specialist I can of course only repeat the arguments of Steinhardt, which I believe are on very strong basis.

1. The parameters characterizing the scalar potential of inflaton field(s) can be chosen freely. This gives infinite flexibility. In fact, most outcomes based on classical inflation do not predict flat 3-space in recent cosmology! The simplest one-parameter models are excluded empirically. The inflaton potential energy must be very slowly decreasing function of Φ: in other words, the slope of the hill along which the field rolls down is extremely small. This looks rather artificial and suggests that the description based on scalar field could be wrong.

2. The original idea that inflation leads from almost any initial conditions to flat universe, has turned out to be wrong. Most initial conditions lead to something very different from flat 3-space: another infinite flexibility destroying predictivity. To obtain a flat 3-space must assume that 3-space was essentially flat from beginning!

3. In the original scenario the quantum fluctuations of inflaton fields were assumed to be present only during the primordial period and single quantum fluctuation expanded to the observer Universe. It has however turned out that this assumption fails for practically all inflationary models. The small quantum fluctuations of the inflationary field still present are amplified by gravitational backreaction. Inflation would continue eternally and produce all possible universes. Again predictivity would be completely lost. Multiverse has been sold as a totally new view about science in which one gives up the criterion of falsifiability.

Steinhardt discusses Popper's philosophy of science centered around the notions of provability, falsifiability, and pseudoscience. Popper state that in natural sciences it is only possible to prove that theory is wrong. A toy theory begins with a bold postulate "All swans are white!". It is not possible to prove this statement scientifically because it should be done for all values of time and everywhere. One can only demonstrate that the postulate is wrong.

Soon one indeed discovers that there are also some black swans. The postulate weakens to "All swans are white except the black ones!". As further observations accumulate, one eventually ends up with not so bold postulate "All swans have some color.". This statement does not predict anything and is a tautology. Just this has happened in the case of inflationary theories and also in the case of superstring theory.

Steinhardt discusses the "There is no viable alternative" defense, which also M-theorists have used. According to Steinhardt there are viable alternatives and Steinhardt discusses some of them. The often heard excuse is also that superstring theory is completely exceptional theory because of its unforeseen mathematical beauty: for this reason one should give up the falsifiability requirement. Many physicists, including me, however are unable to experience this heavenly beauty of super strings: what I experience is the disgusting ugliness of the stringy landscape and multiverse.

3 The counterpart of inflation in TGD Universe

It is interesting to compare inflation theory with the TGD variant of very early cosmology [K1]. TGD has no inflaton fields, which are the source of the three kind of infinite flexibilities and lead to the catastrophe in inflation theory. Let us return to the basic questions and the hints that TGD provides.

1. How to understand the constancy of CMB temperature?

   Hint: string dominated cosmology with matter density behaving like 1/a$^2 asfunctionofsizescalehasinfinite$ $bang-boundaryofcausaldiamond, whichispartofboundaryoflight-cone-the$M^4 distance between points in light-like radial direction vanishes. This could be the geometric correlate for the possibility of communications and long range quantum entanglement for the gas of strings.

   Note: The standard mistake is to see Big Bang as single point. As a matter of fact, it corresponds to the light-cone boundary as the observation that future light-cone of Minkowski space represents empty Robertson-Walker cosmology shows.

The twistorial lift of the Kähler action - whether it is necessary is still an open question - however forces to reconsider this picture [L2, L3].

1. Space-time surfaces are replaced with their twistor spaces required to allow imbedding to the twistor space of $H = M^4 \times CP_2$: the extremely strong conditions on preferred extremals given by strong form of holography (SH) should be more or less equivalent with the possibility of the twistor lift. Rather remarkably, M^4 and CP_2 are completely unique in the sense that their twistor spaces allow Kähler structure (twistor space of M^4 in generalized sense). TGD would be completely unique!

   The dimensional reduction of 6-D generalization of Kähler action dictating the dynamics of twistor space of space-time surface would give 4-D 4-D Kähler action plus volume action having interpretation as a cosmological term.

   Planck length would define the radius of the sphere of the twistor bundle of M^4 with radius which would be naturally Planck length. The coefficient of volume term is coupling constant having interpretation in terms of cosmological constant and would experience p-adic coupling constant evolution becoming large at early times and being extremely small in the recent cosmology. This would allow to describe both inflation and accelerating expansion at much later times using the same model: the only difference is that cosmological constant is different. This description would be actually a universal description of critical phase transitions. The volume term also forces ZEO with finite sizes of CDs: otherwise the volume action would be infinite!

2. This looks nice but there is a problem. The volume term proportional to dimensional constant and one expects breaking of criticality and the critical vacuum extremal of Kähler action indeed fails to be a minimal surface as one can verify by a simple calculation. The value of cosmological constant is very small in the recent cosmology but the Kähler action of its vacuum extremal vanishes. Can one imagine ways out of the difficulty?

   (a) Should one just give up the somewhat questionable idea that critical cosmology for single space-time sheet allows to model the transition from the gas of cosmic strings to radiation dominated cosmology at GRT limit of TGD?

   (b) Should one consider small deformations of the critical vacuum extremal and assume that Kähler action dominates over the volume term for them so that it one can speak about small deformations of the critical cosmology is a good approximation? The average energy density associated with the small deformations - say gluing of smaller non-vacuum space-time sheets to the background - would be given by Einstein tensor for critical cosmology.

   (c) Or could one argue as follows? During quantum criticality the action cannot contain any dimensional parameters - this at least at the limit of infinitely large CD. Hence the cosmological constant defining the coefficient of the volume term must vanish. The corresponding (p-adic) length scale is infinite and quantum fluctuations indeed appear in arbitrarily long scales as they indeed should in quantum criticality. Can one say that during quantum critical phase transition volume term becomes effectively vanishing because cosmological constant as coupling constant vanishes.

One can argue that this picture is an over-idealization. It might however work at GRT limit of TGD where size scale of CD defines the length scale assignable to cosmological constant and is taken to infinity. Thus vacuum extremal would be a good model for the cosmology as described by GRT limit.

3. There is also second problem. One has two explanations for the vacuum energy and negative pressure. First would come from the Kähler magnetic energy and magnetic tension and second from cosmological constant associated with the volume term. I have considered the possibility that these explanations are equivalent. The first one would apply to the magnetic flux tubes near to vacuum extremals and carrying vanishing magnetic monopole flux. Second one would apply to magnetic flux tubes far from vacuum extremals and carrying non-vanishing monopole flux. One can consider quantum criticality in the sense that these two flux tubes correspond to each other in 1-1 manner meaning that their M^4 projections are identical and they have same string tension.

Steinhardt also considers concrete proposals for modifying inflationary cosmology. The basic proposal is that cosmology is a sequence of big bangs and big crunches, which however do not lead to the full singularity but to a bounce. I have proposed what could be seen as analog of this picture in ZEO but without bounces [L1]. Cosmos would be conscious entity which evolves, dies, and re-incarnates and after the re-incarnation expands in opposite direction of geometric time .

1. Cosmology for given CD would correspond to a sequence of state function reductions for a self associated with the CD. The first boundary of CD - Big Bang - would be passive. The members of pairs of states formed by states at the two boundaries of CD would not change at this boundary and the boundary itself would remain unaffected. At the active boundary of CD the state would experience a sequence of unitary time evolutions involving localization for the position of the upper boundary. This would increase the temporal distance between the tips of CD. Conscious entity would experience it as time flow. Self would be a generalized Zeno effect.

   Negentropy Maximization Principle [?] dictates the dynamics of state function reductions and eventually forces the first state function reduction to occur to the passive boundary of CD ,which becomes active and begins to shift farther away but in an opposite time direction. Self dies and re-incarnates with opposite arrow of clock time. The size of CD grows steadily and eventually CD is of cosmological size.

   In TGD framework the multiverse would be replaced with conscious entities, whose CDs grow gradually in size and eventually give rise to entire cosmologies. We ourselves could be future cosmologies. In ZEO the conservation of various quantum numbers is not in conflict with this.

2. The geometry of CD brings in mind Big Bang followed by Big Crunch. This does not however forces space-time surfaces inside CDs to have similar structure. The basic observation is that the TGD inspired model for asymptotic cosmology is string dominated as also the cosmology associated with criticality. The strings in asymptotic cosmology are not however infinitely thin cosmic strings anymore but thickened during cosmic expansion. This suggests that the death of the cosmos leads to re-incarnations with a fractal zoom up of the strings of primordial stage! The first lethal reduction to the opposite boundary would produce a gas of thickened cosmic strings in M^4 near the former active boundary.

3. It might be possible to even test this picture by looking how far in geometric past the proposed coupling constant evolution for cosmological constant can be extrapolated. What is already clear is that in the recent cosmology it cannot be extrapolated to Planck time or even CP_2 time.

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