The Inflated Universe

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This paper presents a critical review of an article appearing in "The New Physics" edited by Paul Davies in 1989. It is entitled "The Inflationary Universe" and was written by Alan Guth who originated inflation theory. On the third of its 23 pages he has a diagram that tracks the spacial development through time of the standard Big Bang and inflationary models of the universe. The time lines start when the universe was 10^{45} seconds old and extend out to the present time some 10^{17} seconds later. This paper focuses mainly on the first four pages of the article where I point out several scientifically unsound statements and erroneous conclusions still being used by Guth even after his theory had been around 26 years! For instance he says that because of inflation all matter and energy in the universe could have been created out of nothing and that the huge burst of energy it took to inflate the universe came from a phase change. Then he traps himself into an argument which leads to the erroneous conclusion that all the energy in the universe except that coming from gravity is repulsive. In this paper I spell out why these as well as some other statements made by Guth are wrong.

Foreword

In two of my papers which I gathered together a few years ago under the heading of "Why Do Physicists Have So Much Trouble Putting Theories Into Words?", I used several examples involving Special and General Relativity to support the assertion made in the title. I wrote that misstatements, arguments falling apart and even the very meaning of words themselves were among the problems giving physicists the most trouble. One of the illustrations I used came from Roger Penrose, one of today's most brilliant theoretical physicists. He wrote, "We are not to consider gravitational force as real according to Einstein." Since it's inconceivable that Roger would not agree with the Great One, how would the two of them then explain that when you drop a stone from your hand, it accelerates all the way to the ground? Relativity theory may explain how space curves the paths of freely moving bodies, but it can't explain what force moves them in those paths. In this paper I turn to the work of another brilliant, contemporary theoretical physicist, Alan Guth, who had a problem of his own putting theory into words. With his Inflation theory he hypothesized that the universe underwent a brief period of super-fast expansion shortly after the Big Bang. He then claimed that "The Inflationary model offers explanation for the creation of all matter and energy in the universe." But, I ask, if this is what happened, what was the Big Bang supposed to have done? It preceded Inflation and for some 80 years now has generally been regarded as the true origin of the universe whether Inflation happened or not.

In "The New Physics" edited by Paul Davies and published in 1989 Alan Guth and Paul Steinhardt have an article, "The Inflationary Universe", which is an account of Guth's modification of the Big Bang Theory. Theories about the universe's origin as well as its supposed Inflation had been going through strenuous revisions in the ten years before then, and today, 22 years later, they still are. I selected the Guth - Steinhardt article for analysis in this paper not only because Inflation was Guth's idea but also because the article supports a theme that runs through most of my papers written in previous years: how can physicists, some of the smartest people around, have so much trouble when it comes to putting their theories into words?

In Guth's theory Inflations is supposed to have kicked in with a huge burst of energy a split second after the Big Bang when the universe was far smaller than an atom, expanding it until it was trillions of times larger. In another split second it abruptly stopped inflating and returned to the much slower Bang expansion rates. Today Guth's theory is pretty much accepted worldwide. It postulates that the universe appeared out of absolute nothingness about 13.7 billion years ago. Guth calls this "the standard model". When Inflation is added to it, he calls it "the inflationary model". The universe detectable through our telescopes he calls "the observable universe". Today astronomers can reach out through it almost 13 billion light years, nearly back to the universe's beginning. (A light year is the distance light travels in a year, about 5.9 trillion miles.) In a few places in his article Guth touches on the possible existence of a much larger universe in which the observable one is only a tiny speck.

As I'll show, describing the evolution of the early universe requires huge extremes of time and space measurements. Cosmologists deal with these as well as other extremes of scale by using the powers-of-ten numbering system. $10^2 = 100$; $10^3 = 1{,}000$; $10^{-2} = 1/100$, etc. The "power" number indicates how many zeros come after the 1. The minus sign means the number is a denominator instead of a numerator. To multiply two powers-of-ten numbers, add their power numbers. To divide, subtract them. To show how potent this system is, the approximate age of the universe today is 4.25×10^{17} seconds. This seems like a fairly benign figure until you write it all out. Four hundred twenty five thousand trillion, or 425,000, 000,000,000,000 seconds! This is not nearly as fantastically large as some of the numbers that show up when you get into Guth's Inflation though. I'll be using them frequently as I review his article. At these extremes of time and distance measurements, values used by cosmologists are usually just approximate ones. The powers of ten often stand alone and are not multiplied up to give a more exact value as the 4.25 does in the age-in-seconds of the universe that I used above. Going in the other direction, time and distance measurements can be so small, they are simply dropped in some calculations. For instance, Inflation was supposed to start when the universe was 10^{-35} seconds old and stop when it was 10^{-32} seconds old. Its duration should then be $(10^{-32}) - (10^{-35})$ seconds. But since 10^{-35} is only 1/1000 of 10^{-32}, cosmologists usually drop the 10^{-35} and say the universe was about 10^{-32} seconds old when Inflation stopped.

The reason Guth developed Inflation theory is that the Big Bang theory came up with several problems just after its universe began which Inflation was intended to solve. For example, calculations show that the universe's density at creation had to have a certain critical value or we wouldn't be here pondering it. Nor would planet Earth be here either. If it had been created with a density just 10^{-15} (a thousand trillionth) greater than this critical value, it would have stopped expanding long ago and collapsed back into a small ball of super-hot energy way before life had had time to evolve. And if it had been created with a density a thousand trillionth less than the critical density, it would have started expanding much faster than it did. By now it would have been much larger, cold, dark and lifeless, and again we wouldn't be here wondering how it all got started. Its rapid expansion would have run it through the period so quickly when solar systems were beginning to form that life would never have had time to evolve. Thus the odds of the density at creation accidently being within a thousand trillionth either side of the critical one that would have allowed life to appear had to have been practically zero. But

Inflation was supposed to enable the universe to evolve as it has up to now no matter what the density was initially. There are one or two other initial condition requirements besides density for the universe to have evolved as it has. But Guth claims that his Inflation would take care of this too.

The intent of this paper is to show that in trying to solve Big Bang problems, Inflation runs into troubles of its own. Here's one for starters. Guth points out that the temperatures of space measured out in all directions from Earth are about the same 2.7 degrees Centigrade above absolute zero. He asks, how can radiation coming from two different places in the universe billions of light years apart end up at the same temperature? His answer? The only way this could happen would be for the following unlikely initial condition of the universe to have existed. It started out from an infinitely small point. Thus all its radiation would have had to have been at the same temperature. (But. I ask, if anything is going to come out of complete nothingness, why wouldn't it most likely be an infinitely small point?) He then comes up with the solution for this problem. It's in his inflationary model. For a brief 10^{-32} seconds after the Bang all its radiation including light traveled out in every directions at over a billion times light speed, blowing up the size of its sphere of energy almost a trillion trillion times larger than it would have been without Inflation. The effect of this would be to iron out any temperature variations that existed in the universe after it was created by the Big Bang. The reason for this is that, while the magnitude of a temperature variation remained the same, it would be spread out over a space trillions of times larger than it was before Inflation began. But why, I ask, was the uniform temperature of space a problem in the first place when space had to start out as an infinitely small point in which there could be only one temperature?

I think that this problem and some other ones I'll be bringing up in this paper pale in comparison, however, with the problem of how to explain the universe's appearing out of absolute nothingness. Guth is one of the many cosmologists who believe that creatio ex nihilo was probably true. He wrote that with his inflationary model "all matter and energy in the universe could have been created from virtually nothing." But why would he say that? As I said in the Foreword, the Big Bang preceded his Inflation! So the universe was already in existence when Inflation was supposed to have happened. There is another problem for him here also. This time it's in the Bang theory instead of Inflation because postulating that the universe came out of nothing violates one of the most basic and uncontested laws in science, the conservation of mass and energy. It says that energy and matter cannot be created or uncreated. But if this is so, it would mean of course that the contents of the universe must have always been in existence and we don't need either the Big Bang or Inflation!

I'm getting the dimensions, times and densities that I use in this paper from Guth's diagram on page 36 in Davies' "The New Physics". In it the horizontal axis gives age in seconds, and the vertical axis gives radii in meters. It then tracks the evolution of the standard and inflationary models, showing how their radii and Horizons grow over time. Horizons represent how far light has traveled in each model after it was created by the Bang. Guth has his diagram showing that 10^{-45} seconds after the Bang the Horizon light had gone 10^{-37} meters while the universes radius had grown out to 10^{-6} meters, 10^{31} (about ten million trillion trillion) times farther and thus faster than the Horizon light had traveled. This, of course, without any Inflation around to account for it is a gross violation of the law of light speed.

The axes are scaled in powers-of-ten so that the extremes of both very large and very small measurements can fit inside the diagram. The vertical axis runs from 10^{-60} to 10^{60} meters, while the horizontal axis runs from 10^{-45} to a little over 10^{17} seconds, the age of the universe today. Powers-of-ten figures like 10^{60} and 10^{-60} hide the enormities of those numbers; so in this paper I will often put them in their verbal forms like the "ten million trillion trillion…" I used above in order to dramatize their incredible extremes. Results like this as well as the time and distance measurements given in this paper could be off by a few orders of magnitude because of the small size of the diagram making it visually difficult to pair locations with measurements. But that wouldn't affect their unreal extremes which are one of the main topics of the paper. On the last page I've added a simplified version of Guth's diagram to help one see better exactly how it works.

As I wrote above, Inflation is supposed to have started when the universe was about 10^{-35} seconds old and ended when it was about 10^{-32} seconds old. According to Guth within that time the radius of the standard model of our observable universe grew from 10^{-1} meters to about 10^{0} meters (1 meter). The inflationary model grows it out to the same 1 meter within the same time. But Guth started it out with a radius of only about 10^{-57} meters, thus making it a billion trillion trillion trillion trillion times smaller than the standard model was at the same age. This comparison is so grossly unbalanced that it is meaningless to try to use it in the construction of a scientific theory let alone for anything else! It thus constitutes still one more problem for him.

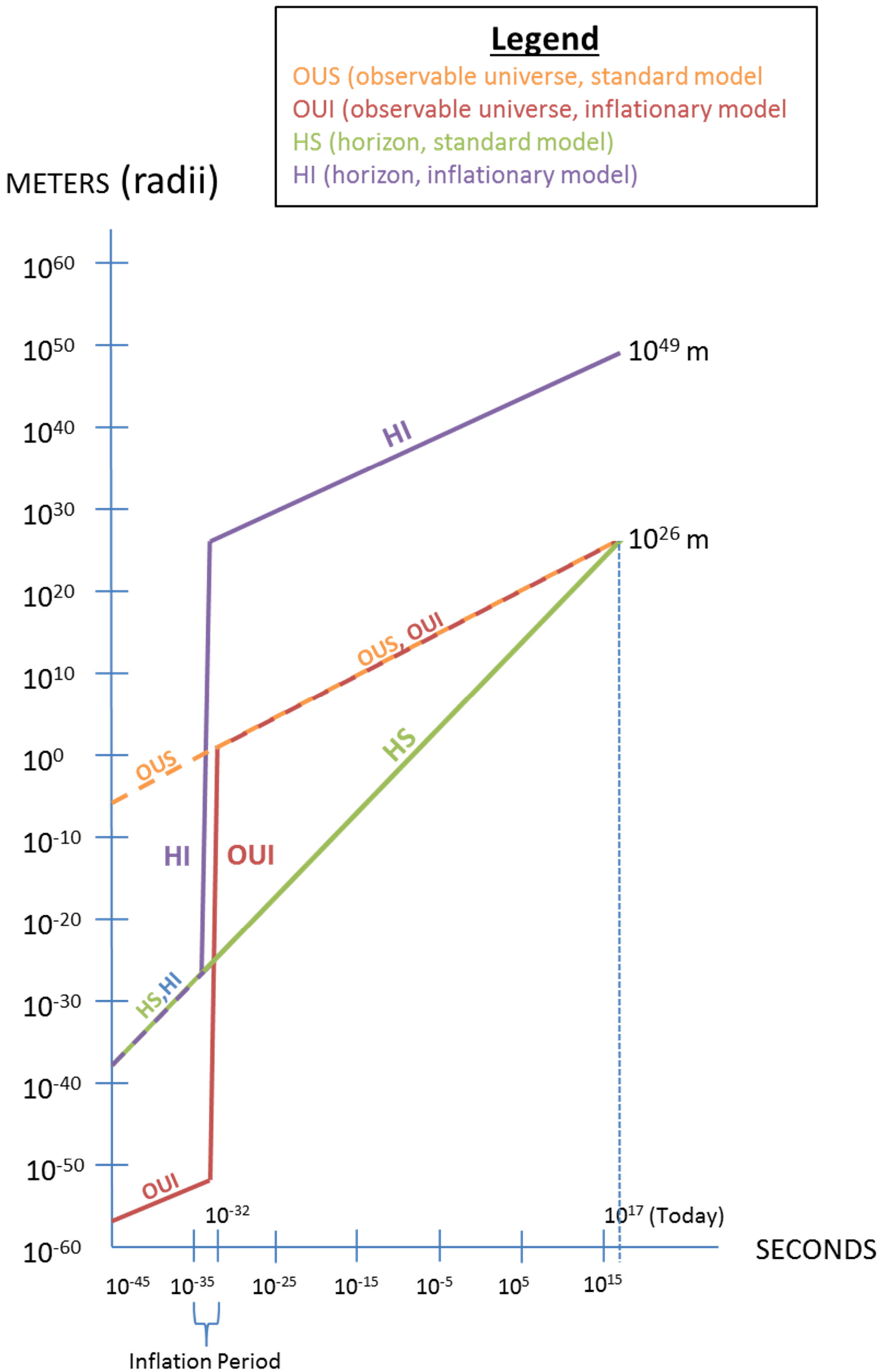
But his troubles are not over yet. If Inflation actually happened, it must have taken a humungous burst of energy. It shot the light from the Bang over 1½ light years out into space in about a billion trillion trillionth of a second. Where could this burst of energy have come from? Here is his explanation. Inflation is based on what physicists call a phase change. An example of this occurs when you put water into a freezing environment and it starts turning into ice. As thermal energy leaves the system of freely moving water molecules, they gradually slow down as the temperature keeps dropping until they suddenly fuse together in large numbers from their liquid phase into a solid phase. They lose all their velocity as they bond into highly ordered crystal lattices over extended areas. According to Guth's theory the same sort of thing happened to the universe shortly after the Bang. But in his article he really struggles to make his water-into-ice analogy fit what happens in Inflation, referring several times to things like liquids cooling and then crystalizing. The mighty billion trillion trillionth-of-a-second burst of energy was apparently supposed to come from the phase suddenly changing from the radiation energy of photon particles into the kinetic energy of material particles when the very early universe was about 10^{-35} seconds old. But there's little resemblance between what happens in Guth's inflating universe and what happens in phase changes here on Earth. His diagram shows that a hot, gaseous universe didn't suddenly become more ordered and turn into a liquid or a solid. Before Inflation it was a hot, expanding ball of energy and particles. And after Inflation ended it was still a hot, expanding ball of energy, but now with more particles and homogeneity and a little less heat. There isn't much phase change in that.

More of a problem for Guth, though, is this flight of fancy. "It's likely we're living in a region with a size of 10^{35} light years or more." But that would be about a trillion trillion trillion times larger than our universe! And this super gigantic structure, inside of which our observable universe would be only a tiny speck, was supposed to be created out of completely NOTHING, a state in which there was no matter, no energy, not even any time or space?

Finally, he returns to the nothingness issue one last time, apparently trying to find a rational explanation for how just the energy alone of the universe could possibly have been created ex nihilo. He starts out with gravitational energy and writes "Gravitational energy is negative…" He's obviously referring to the fact that it had always been found to be attractive and not repulsive in its effects. But then he continues with "and…it precisely cancels …non-gravitational energy…" But this implies that all non- gravitational energy must be repulsive which of course is not true. A positive electrically charged particle always attracts a negatively charged particle and vice versa. Let's assume that Guth was just careless in throwing in this little piece of theorizing without giving it much thought and that he really meant to include all energy and not just gravitational energy so that his argument could run something like this. "All energy was created ex nihilo by dividing nothingness into two equal but opposite parts, positive and negative energy." But this far- fetched creatio would still hold a problem for him. What would pull and push nothingness apart when there would be nothing around to do the pulling and pushing in the first place?

Well, here I am at the end of the paper still scratching my head over how bizarre the models of the universe are that I got out of Guth's diagram. Before I was through, I had found seven problems in his article, most of them in the first four of its twenty three pages. A question that kept recurring in my mind as I worked on this paper was, where did Guth get the time and distance numbers he used in the diagram when the universe was less than 10^{-32} seconds old? He never tells you even though his diagram is built off of them! After their appearance on the third page I could find only one brief place in the remaining 20 pages where he even brought up the subject of time and distance numbers!

Guth obviously went much further into his theory than I did, and you come across some amazing claims. In one place we find that Inflation was caused by a one hundred million trillion trillionth- of- a- second enormous burst of negative gravity (which had never been observed) from a false vacuum (a state of matter that's never been observed) involving Higgs particles (which have never been observed conclusively) which rapidly decay into lighter particles (which, at last, have been observed. They are the familiar elementary particles like the electron.) It's beyond my level of competency in physics to get into things like Higgs particles, but what about the questions I did bring up? They covered aspects of Guth's theory that are well within the range of comprehension of us amateurs. Most of them involved just simple calculations using measurements there for all to see in his diagram whatever their merit. As I indicated at the beginning of this paper, I've often written about how much trouble physicists have in putting theories into words. But here in Guth's case I think there is a much more fundamental problem. He was in trouble before he even got into his theory.


Legend
OUS (observable universe, standard model
OUI (observable universe, inflationary model
HS (horizon, standard model)
HI (horizon, inflationary model)
METERS (radii)
10^60
10^50
10^40
10^30
10^20
10^10
10^0
10^-10
10^-20
10^-30
10^-40
10^-50
10^-60
10^49 m
10^26 m
HI
OUS, OUI
HS
OUS
HI
OUI
HS,HI
OUI
10^-32
10^17 (Today)
SECONDS
10^-45
10^-35
10^-25
10^-15
10^-5
10^5
10^15
Inflation Period