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OPINION ARTICLE

REVISED Does standard cosmology really predict the cosmic microwave background? [version 2; peer review: 1 not approved]

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Abstract

In standard Big Bang cosmology, the universe expanded from a very dense, hot and opaque initial state. The light that was last scattered about 380,000 years later, when the universe had become transparent, has been redshifted and is now seen as thermal radiation with a temperature of 2.7 K, the cosmic microwave background (CMB). However, since light escapes faster than matter can move, it is prudent to ask how we, made of matter from this very source, can still see the light. In order for this to be possible, the light must take a return path of the right length. A curved return path is possible in spatially closed, balloon-like models, but in standard cosmology, the universe is “flat” rather than balloon-like, and it lacks a boundary surface that might function as a reflector. Under these premises, radiation that once filled the universe homogeneously cannot do so permanently after expansion, and we cannot see the last scattering event. It is shown that the traditional calculation of the CMB temperature is flawed and that light emitted by any source inside the Big Bang universe earlier than half its “conformal age”, also by distant galaxies, can only become visible to us via a return path. Although often advanced as the best evidence for a hot Big Bang, the CMB actually tells against a formerly smaller universe and so do the most distant galaxies. An attempt to invoke a model in which only time had a beginning, rather than spacetime, has also failed.

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In the *Introduction* (last passage), it is made explicit that blackbody radiation needs a confinement in order to remain within a region.

Under *Model 2*, it is made clearer that, in a Big Bang universe, it is not the case that blackbody radiation lost from a region is balanced by an equal amount gained from outside.

Model 4 has been extended with an analytic description of the present standard model, in which a “cosmogonic” flat and non-reflective Big Bang model, in which the universe expanded out of a singularity in spacetime, is supplemented with a vaguely imagined “chronogonic” Expanding View model in which the universe has always had at least its present size, while time arose 13.7 Gyr ago. The CMB radiation density is still calculated under the incorrect assumption of balanced radiation losses in a “photon gas” (Ryden, 2016) that co-expands with the material universe. An origin of the CMB in a spherical surface from which it has taken the photons 13.7 Gyr to reach us directly by now is compatible with the Expanding View model. A non-reflective flat Big Bang universe contains no points from which it would take so much time, but an Expanding View universe, in which the scale factor has never been smaller than now, can neither give rise to a homogeneous last scattering surface nor to a cosmic redshift. CMB and redshift might have other origins and reasons, but the standard model offers none. In any case, the constancy of the scale factor contradicts its increase with time in the radiation density calculation.

In the next to last passage of the *Discussion*, there is now a reference to Lakatos (1976), who found the “hard core” of currently accepted scientific doctrines to be beyond criticism.

Any further responses from the reviewers can be found at the end of the article

Introduction

In 1964, Penzias & Wilson (1965) serendipitously discovered the cosmic microwave background (CMB), a thermal radiation with a temperature of 2.7 K. Prior to this, the presence of a cosmic heat bath with a temperature of a few K had already been conjectured by several researchers on various grounds unrelated to the Big Bang (Assis & Neves, 1995). Based on absorption lines of interstellar CN-molecules, McKellar (1940) had suggested a maximum temperature of interstellar space of no more than 2.7 K. Alpher & Herman (1948) and Alpher *et al.* (1967), who were contemplating thermonuclear reactions in the expanding universe (for historical perspectives see Naselsky *et al.* (2006) and Alpher (2012), expected a thermal radiation with about 5 K as a residual of a hot Big Bang. In this, they built on Tolman’s studies (Tolman, 1931; Tolman, 1934) of model universes filled with blackbody radiation as a thermodynamic fluid, so that “*The model of the expanding universe with which we deal, then, is one containing a homogeneous, isotropic mixture of matter and blackbody radiation*” (Alpher & Herman, 1975). They did not really discuss and clarify under which conditions such a state is sustainable in Big Bang models.

When Penzias & Wilson (1965) were bothered by the presence of unexpected radiation, another group of scientists (Dicke *et al.*, 1965) did expect it in a hot Big Bang model and was developing an experiment in order to measure it. After asking whether the universe could have been filled with

black-body radiation from its possible high-temperature state, they say “*If so, it is important to notice that as the universe expands the cosmological redshift would serve to adiabatically cool the radiation, while preserving the thermal character. The radiation temperature would vary inversely as the expansion parameter (radius) of the universe.*” This is also what Tolman (1934) said.

Dicke *et al.* (1965) were initially in favor of a model in which the universe expands, slows down and contracts to a minimal size (not necessarily a singularity), for a new cycle to begin, but they concluded that “*with the assumption of general relativity and a primordial temperature consistent with the present 3.5°K, we are forced to adopt an open space, with very low density.*” (Dicke *et al.*, 1965). They had expected the temperature to exceed 30 K in a closed space.

In subsequent Big Bang models, the universe expanded from a very dense and opaque initial state in which it was filled with a hot and dense plasma consisting of protons, electrons and photons colliding with these. When the plasma had cooled sufficiently by the expansion of the universe, electrons and protons combined into H atoms. This event is still referred to as “recombination”, although cyclic models had lost support in the late 1990s, when an accelerated expansion suggested itself (within the Big Bang paradigm) in the redshift-magnitude relation of supernovae (Perlmutter, 2012; Riess, 2012; Schmidt, 2012) instead of an expected decelerated one. Only after recombination and decoupling, when the charged particles had been neutralized, the photons could move freely.

It is now commonly estimated that the universe became transparent about 380,000 years after the Big Bang (Smoot, 2007), when it had cooled to about 3000 K. The thermal radiation is said to have been emitted from a “last scattering surface” (LSS) and to have retained its blackbody spectrum because it expanded adiabatically. Due to the ever continuing expansion, which uses to be ascribed to “space”, the light waves were stretched and their energy density decreased. The wavelength at which the radiation is strongest, which according to Wien’s displacement law is inversely proportional to temperature, would have become roughly 1100 times longer since the radiation was emitted (Bennet *et al.*, 2003), while the temperature decreased to the present 2.7 K. Since the 1970s, the presence of this radiation has routinely been advanced as the strongest piece of evidence for a hot Big Bang.

The idea that the CMB comes directly, although redshifted, from a last scattering surface emerged only after 1965. It is not clear how the early followers of Tolman (1934) thought about this, but it requires normally a confinement in order to keep blackbody radiation within a region, and the questions of what constitutes or substitutes the confinement of an expanding universe and which difference the motion or absence of a boundary surface would make were not treated critically. The problem we are concerned with here arose at the latest when these questions were still not treated critically when the assumption of a directly viewed LSS had made them crucial.

The problem

If one considers the following question, one can easily see that Big Bang cosmology requires the universe to be suitably confined or curved in order for radiation from the LSS to become visible at all.

If the CMB originated at the last scattering surface

and all matter originated within the region enclosed by this surface,

while light escaped from there at c , maintaining this velocity for eons,

and the matter of which we consist left the same region more slowly,

then, how can it be that we can see the light?

With these premises, we cannot reasonably be ahead of the light. The ‘flash’ of light from the LSS had a substantial duration, but it must have passed our place very long ago. Now, it could only become visible at our place if the light had been reflected back to us or taken a curved return path of the right length. In a model, this needs to be specified. Before turning to the standard model, which will be shown to be inconsistent, let us first consider a non-reflective “flat” model and then briefly also reflective versions and a positively curved model.

Model 1. In a non-reflective flat Big Bang model (curvature 0), light will escape from the expanding material universe and proceed farther at velocity c . The material universe will be surrounded by an expanding empty region inside a spherical shell that contains radiation, perhaps also cosmic rays, but no ordinary matter. In such a universe, the conditions assumed by Tolman (1931); Tolman (1934) and presupposed by his followers are not permanently retained after last scattering. However, the belief that radiation from a past epoch, named “relic radiation” or “residual radiation”, could permanently fill the whole volume of an expanding, formerly smaller universe even in the absence of a reflective boundary surface or a suitable “curvature” was inherent in the reasoning by Alpher & Herman (1948); Alpher *et al.* (1967) and Dicke *et al.* (1965), and it has remained so in the more recent literature, e.g. Peebles *et al.* (1991) and Peebles (1993). Alpher & Herman (1975) described their expanding universe in retrospect as “one containing a homogeneous, isotropic mixture of matter and blackbody radiation”. This can and should be read as a warning against uncritical adoption, since the authors did not reason about how such a state could maintain itself over time, given the speed difference between radiation and matter. Dicke *et al.* (1965) stated that “The radiation temperature would vary inversely as the expansion parameter (radius) of the universe”. Their calculation presupposes the radiation to fill their expanding universe permanently. Likewise, Peebles *et al.* (1991) wrote: “In the standard model, ... space was (and is) filled with black-body radiation, the cosmic background radiation”, but the “(and is)” qualifies as a non-sequitur. Correctly and transparently reasoned,

radiation from a past epoch fills, at each instant, only the volume that is traversed by the rays or “future light cone” from that epoch.

For an origin at the LSS and no reflection, this volume is represented by the golden V-shaped band in Figure 1. The band stands for a radiation-filled shell whose thickness remains, in comoving units, constant and equal to the diameter of the LSS. The shell surrounds an expanding volume that contains no such radiation. In such a universe, the LSS will no longer be visible to anybody who has moved at $v \ll c$ when more time has passed than what light needed for crossing the universe just after it had become transparent (the vertical width of the golden bands in Figure 1). The actual CMB we see now thus could not possibly have originated there.

Model 2. In a flat Big Bang universe that is surrounded by a boundary surface, light can be reflected there. Complete reflection occurs if the impedance of space becomes infinite (or zero) there. If space just loses its existence at an “edge”, the impedance becomes undefined, which is problematic, but the location of the reflective surface is also problematic. In order for the CMB to become visible, the reflection must occur at a certain distance from us, within the future light cone of the LSS. If the reflection occurred at a constant distance from us, this could work in our epoch, but the CMB would not have been visible between our epoch and the time when the direct view of the LSS was lost. If the reflection formerly occurred at a smaller distance, the CMB may have been visible then, but this would have blocked any later view from a larger distance. An elaborate model that avoids this problem and/or describes a view via repetitive reflections at opposite surfaces does not appear to have been proposed.

The present standard model is in some respects equivalent to model 2. In it, the expansion is described by the scale factor $a(t) = (1 + z)^{-1}$, which is applied to co-expanding structures in three dimensions and also to the dimension of time, while

it is disregarded that radiation not only expands in these four dimensions but also escapes from its origin at c

and so disappears from direct view, remaining within the golden band in Figure 1. This traditional disregard is an embarrassing blunder.

The disregard would be justified if and as long as the radiation lost from a region was balanced by an equal amount gained from outside. The conditions for this to happen have traditionally been assumed to be met, but this has apparently never been analyzed critically. In a Big Bang universe it is fairly clear from Figure 1 that radiation is lost from a co-expanding region by propagating forward within the golden band while nothing can be gained from outside the universe.

The disregard would also be justified if the material universe was surrounded by a reflective “firmament” whose diameter

Figure 1. Spacetime diagram of flat Big Bang universe. Abscissa: comoving distance χ in Glyr. Ordinate: conformal time η in Glyr. V-like golden band: future light cone of last scattering surface (LSS, red horizontal dash close to zero-point, visible directly only from within golden band). Blue Λ -like trace: our past light cone – we at its peak, not in golden band. Region beyond golden band (dotted extension of blue trace) has not come into existence. In standard cosmology, galaxy GN-z11 and fictitious LSS placed in this region nevertheless (the latter at $\chi \approx \pm 46$ Glyr). Between dashed vertical lines: confined universe that co-expands with material universe (co-moving diameter constant and equal to that of LSS, mentioned under model 2). So confined, LSS remains permanently visible. Place of GN-z11 in this model and zigzag path to us via 17 reflections also shown. Dotted horizontal lines: see Table 1. Last scattering at $\eta \approx 0.95$ Glyr, $t \approx 0.38$ Myr; last visibility of LSS and blackbody conditions at $\eta \approx 1.9$ Glyr, $t \approx 1.95$ Myr.

Table 1. Values of scale factor a , redshift z and age t of the universe, listed for conformal times η represented by dotted horizontal lines in Figure 1.

Conformal time η (Gyr)	a	z	t (Gyr)	Notes
46.7	1	0	13.7	Now
35.8	0.5	1	5.95	
23.35	0.21	3.76	1.70	Conformal halftime
15.9	0.1	9	0.56	
4.5	0.01	99	0.017	
1.0	0.001	999	0.00044	

Values based on 5-year WMAP data and Λ CDM model computed using WolframAlpha®.

also expanded at $a(t)$. This diameter would, then, remain constant in units of comoving distance, which is a distance measure in which the expansion of the universe has been factored out (consider the dashed vertical lines in Figure 1). If the enclosed space in these units was as large as the LSS, it would indeed remain homogeneously filled with reflected

radiation, and the CMB would evolve as traditionally assumed and taught, e.g., in Chapter 6 of Peebles' (1993) authoritative textbook. However, such a reflective firmament is for good reasons not specified in standard cosmology. It would be incompatible with the cosmological principle even in its imperfect form (which already allows violation in the dimension of time). It remains also unclear how matter that hits the firmament would interact with it.

Model 3. In a positively curved Big Bang model (curvature +1), which, reduced by one dimension, can be imagined as the surface of an inflating balloon, the LSS could be visible because these models allow a return path of light. This visibility can be expected to evolve with the expansion factor of the universe from continuous to periodic before finally being lost. Here, we shall not delve into the question under which premises it could be permanent or be lost entirely, because it would require assumptions that are not made in standard cosmology. Instead, when analyses of high-resolution maps of the CMB were found to be compatible with a flat universe (Davis *et al.*, 2007; de Bernardis *et al.*, 2000) rather than with a positively curved one, the flat universe became adopted as the standard. This flatness came unpredicted and posed a “coincidence problem” (Debono & Smoot, 2016). Recently, based on CMB data from the Planck mission, a positive curvature has been argued for

(Di Valentino *et al.*, 2019), but this is not a feature of the present standard model.

Model 4. In the present standard model (Ryden, 2016; Smoot, 2007), a “cosmogonic” flat and non-reflective Big Bang model (model 1), in which the universe expanded out of a singularity in spacetime, is supplemented with a vaguely imagined model in which the universe has always had at least its present size, while time arose 13.7 Gyr ago. In this model, the radiation sources that were visible shortly after time onset were all cosmically nearby. As time passed on, the span of distances at which sources could be seen became successively wider. Events that occurred shortly after time onset were visible ever since. This makes the attributes “Expanding View” and “chronogonic” adequate for this model.

In the present standard model, the CMB radiation density is still calculated in the traditional manner as if the Big Bang universe was filled with a photon gas (Ryden, 2016) that co-expands with the material universe and that, as assumed already by Tolman (1934), gains from its surroundings exactly as much as it loses to them. The number density of photons would thus remain the same in comoving coordinates. This is in its outcome essentially the same as if the material universe was surrounded by a reflective sphere that co-expanded with the LSS, as in model 2. If this is assumed to hold in a Big Bang universe without confinement, it involves the blunder mentioned under *Model 2*: in a Big Bang universe, there is nothing to be gained from its non-existent (or at least empty) outside.

As can be seen in Figure 1, the points of origin are located *outside* the space that was brought into existence by the Big Bang, whose future light cone, from another point of view referred to as the “particle horizon”, delimits this space. In this Figure, the apparent places of origin of the CMB, which define a fictitious LSS, are maximally remote, in comoving distance about ± 45.7 Glyr farther away from the original LSS, at which the temperature is calculated to have been 3000 K at decoupling, i.e., at $t = 380$ kyr. In terms of comoving distance, the extension of this surface had then already grown to almost ± 1 Glyr, but no more than that. Note that the use of ordinary, unexpanded coordinates would make the place-discrepancy much smaller, but it would not make any difference to what is inside and outside the Big Bang universe.

The assumed place of origin of the CMB in a spherical surface or shell around our position, from which it has taken the photons 13.7 Gyr to reach us directly by now, is compatible with the Expanding View model. A flat Big Bang universe in which no reflection occurs contains no points from which it would take so much time, but a chronogonic universe, in which the scale factor has never been smaller than now, can neither give rise to anything like a homogeneous LSS nor to a cosmic redshift. The CMB and the cosmic redshift might have other origins and reasons, but we are here only concerned with standard cosmology, which offers no alternative. In any case, a constant scale factor contradicts its increase

with time in the radiation density calculation. This makes the supplemented model inconsistent.

While CMB photons may actually require 13.7 Gyr to reach us from their source, and the Universe may well be flat and infinite, a flat and reflection-free Big Bang universe does not provide the spacetime that would be necessary in order to accommodate a ray (a null-geodesic) of the corresponding length. If a ray of this length is to end at us, it must have its origin outside the Big Bang universe. This may well be so, but if this is accepted, as it is in the Expanding View model, then, the very idea of a Big Bang is untenable and, if reason rules, thereby already rejected. It is then irrational to calculate the properties of the CMB on the basis of its origin at a LSS inside a Big Bang universe and simultaneously to admit its origin at a maximally remote place outside the said universe, where the conditions are very different if ascertainable at all. The custom of pretending that processes such as “last scattering”, “decoupling” etc., would occur also in a chronogonic universe, is deceptive.

The zero-point of time in the chronogonic Expanding View model is an intellectual relic from Big Bang models. In these, it is the time at which there was a singularity in space. If this singularity in space is removed, as it is in the chronogonic model, then any zero-point in time will be arbitrary and must be physically inconsequential. This implies that the radiation density in the universe cannot have been higher at points in time that were closer to the zero-point than we are now. Thus, in the cosmogonic model, the LSS existed but cannot be seen by us, while in the chronogonic model it never existed at all. If this is to be amended, we have to go for a model that is neither cosmogonic nor chronogonic, but in which the universe, if it is homogeneous at the largest scale, always can have shown the same appearance at this scale.

Figure 1 illustrates the relevance of the problem to other observables than the CMB as well: in a flat geometry,

our direct view is limited to events that happened after the universe had attained half its present age in conformal time (at $\eta \approx 23.35$ Gyr).

This corresponds to $t \approx 1.7$ Gyr, scale factor $a(t) \approx 0.21$ and redshift $z \approx 3.78$. It is noted as “conformal halftime” in Table 1. In order for earlier events to be seen, Big Bang cosmology requires light to take a straight or curved forward and return path. This appears to have gone unnoticed by observers of distant galaxies. About GN-z11, with redshift $z = 11.09$, it is reported that “This indicates that this galaxy lies at only ~ 400 Myr after the Big Bang” (Oesch *et al.*, 2016), at $a(t) \approx 0.083$. This actually puts the galaxy, shown in Figure 1, far beyond the future light cone of the Big Bang. If anything exists in this spacetime region, it cannot have arrived there from the presumed ultimate origin of matter. The first galaxy that, with $z = 3.8$, was too far away to be seen directly in a Big Bang universe had been observed already in 1987 (Chambers *et al.*, 1990). If galaxies at $z > 4$ cannot even be located within

such a universe, it is no longer a surprise that they do not show the evolution they should according to the hierarchical merging paradigm that has become part of concordance cosmology (Steinhardt *et al.*, 2016).

In stark contrast to what is traditionally claimed, the CMB actually tells against a formerly smaller universe and so do the most distant galaxies. The visibility of these has not been reconciled with the idea of a Big Bang. The related attempt to do so has led to a confused use of models that are incompatible with each other. The need for invoking the Expanding View model would disappear if we actually saw mirror images [as in model 2], but in order for galaxies to be seen in this way and the actual isotropy of the CMB to be obtained, the reflector would need to be of all too spectacular stability and flatness - like that required in a telescope of giga-lightyears in length.

Discussion

Because of the inherent inconsistency of the standard Λ CDM concordance cosmology, here represented by model 4, it does not come as a surprise that “*misconceptions and confusions have long been common in papers on cosmology, also in many by renowned authors*”, as reported by Davis & Lineweaver (2004). These authors deserve credit for having paid attention to those. However, they did not either notice that early events cannot be seen directly. In proceeding without considering reflections (last passage of their section 3.3), they mistook the intersection between our past light cone and the future light cone of the LSS [where a reflection would need to occur] for “*the points from which the CMB was emitted*” (Davis & Lineweaver, 2004, p. 101). Although this is not yet beyond the particle horizon of the Big Bang, it would still be off target by half as much as model 4. The confusion arose by equating this particle horizon with the surface of last scattering, which the authors refer to as “*our effective particle horizon*” (Davis & Lineweaver, 2004). It also disagrees with the caption of their Figure 1, which presupposes model 4 as such.

When Tolman (1931) considered “*the highly idealized model of a non-static universe filled with black-body radiation as a thermodynamic fluid*”, he did not discuss the implications of the large size of the universe and the possible absence of a reflective confinement or its equivalent. It deserves to be noted that the time required for cavity radiation to attain a desired degree of homogeneity (after a sufficient number of reflections) increases in proportion to the linear size of the cavity. In a Big Bang universe, this will even with modest demands take much longer than its age. If there is no boundary surface other than one that recedes at c , we have seen that any old radiation will eventually disappear from view. In a flat and non-reflective Big Bang universe [model 1 above and its equivalent in model 4 before being supplemented], this must happen to the radiation from the original LSS, which, thus, cannot remain visible. The CMB must have a different source, whose identification exceeds the scope of this paper.

While the irrationality of the assumption about the visibility of radiation from a past epoch in a Big Bang universe, which was disclosed in *The problem*, can be clearly seen in a space-time diagram such as Figure 1, it may be missed if the ordinary coordinates of time and distance are used, especially if a past light cone is shown (in these coordinates shaped like an avocado seed) that continues below $t = 1.7$ Gyr down to the origin, while it is not made evident that the region it traverses there lies outside the Big Bang universe. For examples see the “avocado seeds” in Davis & Lineweaver (2004), more detailed in Whittle and without any scale under “Manipulating Space-Time Diagrams” in Wright.

The fact that the irrationality has remained unnoticed by professionals is an instance of the ordinary uncritical passing down of human culture, of languages, myths, etc. from generation to generation. In this wider cultural context, science stands out as an exceptional, more critical endeavor that requires practitioners not simply to accept and adopt what they were taught, but to check the relevant assumptions and doctrines for consistency and tenability and to recheck them when premises and/or relevant knowledge change. This may sometimes fail to happen, especially in cases like this, where the presence of an inconsistency became potentially clear only gradually, here after 1965, when a teaching practice had already established itself since Tolman (1934). This practice appears to have prevented the disclosure of the irrationality, which would likely have become obvious after a fresh look at the facts. It is in line with this and with Lakatos' (1976) analysis of research programs that the rejection of the idea of a Big Bang has been blocked in model 4, although the evidence that requires the rejection has been accepted. Blockage of this kind tends to foster more or less absurd speculation. While scientific journals often tolerate speculative ideas like “inflation” and the “multiverse”, which have been left out of consideration here, it is unfortunate that most of them refuse through prejudice to publish any paper that discredits the “hard core” (Lakatos, 1976) of the currently accepted doctrine within their field from inside. For editors, it is rational to reject such papers right away: these might threaten their reputation if later shown to be erroneous. Also for reviewers who lack a critical attitude against the established practice and doctrine, it is a priori inconceivable that the whole community of well-educated professionals, here mainstream cosmologists, could have made the same cardinal blunder. This holds also in cases like this one, in which the presence of at least one inconsistency is obvious to the uncommitted.

Although the deficiencies disclosed here can be judged as completely unacceptable, other ones need to be addressed as well (López-Corredoira, 2017; Merritt, 2017; Spergel, 2015; Traunmüller, 2014; Traunmüller, 2018). Just consider that both Λ (dark energy) and CDM (cold dark matter) have remained in the imaginary realm and so merely represent mythical factors or immunizing tactics (also called “conventionalist stratagems”) that protect a doctrine from empirical falsification (Merritt, 2017). Approaches that rely on such factors are at

least excessively speculative, but inconsistencies such as the two revealed here must be desisted from in any discipline that is meant to qualify as rational. In order to progress, one should preferably eliminate any old deficiencies instead of suggesting some fancy new physics that might hide them. One should rather strive for well-foundedness in the physical principles

(Traunmüller, 2018) than merely for a rationalized mythology, but it is, of course, even more fundamental to respect reason at all.

Data availability

No data are associated with this article.

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Indranil Banik

Helmholtz Institute for Radiation and Nuclear Physics (HISKP), University of Bonn, Bonn, Germany

The author's model 4 (supposedly representing the standard model) does not adequately represent the standard picture. In particular, the author has made the so-called chronogonic assumption that the cosmic scale factor $a(t)$ was never smaller than now. But in the standard model, it has increased by a factor of 1090 since the time of last scattering.

Regarding the photons having a constant co-moving number density, this is correct - but the author still says it is wrong. This is because the author assumes some sort of finite Universe, with a single flash occurring 13.8 Gyr ago and illuminating some region outside which there is nothing. This is evident from Figure 1 and the authors statement "there is nothing to be gained from its non-existent (or at least empty) outside" - in the standard picture, there is no outside. Rather, the standard picture is that an infinitely large Universe appeared instantaneously 13.8 Gyr ago, and then $a(t)$ started rising rapidly. **All of space was brought into existence by the Big Bang.** This is why in co-moving terms photon losses from some region are always (on average) balanced by photons gained from elsewhere. There is also the additional redshifting of photons by which they lose energy individually, but certainly the co-moving number density of photons should remain the same.

In Figure 1, this leads to the author only considering photons emitted from one point on the last scattering surface. In reality, what would be more useful is to draw two more multiple orange last scattering surface (LSS) cones translated along x , such that they pass through our spacetime location (at the top). The apexes would be where the dotted blue lines intersect with (almost) zero conformal time. This would more accurately represent what happened in the Big Bang according to standard cosmology, and also address the issue of why GN-z11 is currently visible. It is well known that this does lead to a causality problem in that all these LSS cones have an apex at widely separated points, so shouldn't have been in causal contact even earlier - and thus should have a different temperature. This problem is addressed by the inflationary hypothesis.

Another issue is that some sort of confinement is needed to get blackbody radiation, but the author mistakenly assumes that the whole Universe must have some sort of reflective boundary.

In reality, the confinement arises because the early Universe was opaque because neutral hydrogen atoms did not exist yet, and electrons have a large Thomson scattering cross section. So photons had only a short mean free path/travel time between absorptions. This is really the origin of the blackbody spectrum - not the walls of the Universe, which would be more analogous to terrestrial experiments involving a sealed-off room.

At the end of page 7, the author states without justification that the visibility of high- z galaxies has not been reconciled with a hot Big Bang. There is no problem with this in the standard context - the galaxy would have been relatively close to us, but in an expanding universe, light from it would only just have been able to keep pace with the ever increasing distance remaining to the Earth. Most of the progress would be achieved at late times when the Hubble parameter was lower. The total travel time would be almost 13.8 Gyr. There is nothing unusual about this, in an infinite Universe. The problem with the authors's logic is that a finite Universe is assumed, which would indeed cause very serious problems.

Although the last part on the sociological aspects is reasonably well done, I strongly recommend the author delete this last bit: but it is, of course, even more fundamental to respect reason at all.

In conclusion, the fundamental assumptions underpinning the article are completely incorrect for the reasons I have explained. Therefore, I still have to recommend rejection of the revised article, and also recommend that in future other reviewers be used in order to get a second opinion. My opinion is that it is not possible to edit the article in such a way that it can ever be approved, since the only novel claim in the article is that all standard cosmologists over the past 80 or so years have made a basic blunder - but it is completely clear to me that the blunder is on the part of the author, who has not understood the most basic aspects of the standard hot Big Bang cosmological model.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Modified Newtonian Dynamics (MOND). I felt I was able to assess all aspects of the article, as I work on a non-mainstream cosmological model and need to pay close attention to issues like the cosmic microwave background radiation and cosmology, which remains a little uncertain in MOND

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 27 Jun 2020

Hartmut Trautmüller, Stockholm University, Stockholm, Sweden

Reviewer's comment: The author's model 4 (supposedly representing the standard model) does not adequately represent the standard picture. In particular, the author has made the so-called chronogonic assumption that the cosmic scale factor $a(t)$ was never smaller than now. But in the standard model, it has increased by a factor of 1090 since the time of last scattering.

Author's response: I think I made it clear enough under *Model 4* that two incommensurable models are confounded with each other in the present standard model, but I was not explicit enough about their incompatible characteristics. The basic model is the traditional, 'cosmogonic' FLRW Big Bang model, in which $a(t)$ has increased as the reviewer says. The 'chronogonic' supplementary one has its origin in the assumption of a homogeneous universe. This and the characteristics of both models are now made explicit in the first passage under *Model 4*. Under *Model 1*, I have inserted a new passage that prepares the reader for this.

Reviewer's comment: Regarding the photons having a constant co-moving number density, this is correct - but the author still says it is wrong. This is because the author assumes some sort of finite Universe, with a single flash occurring 13.8 Gyr ago and illuminating some region outside which there is nothing. This is evident from Figure 1 and the authors statement "there is nothing to be gained from its non-existent (or at least empty) outside" - in the standard picture, there is no outside. Rather, the standard picture is that an infinitely large Universe appeared instantaneously 13.8 Gyr ago, and then $a(t)$ started rising rapidly.

Author's response: This is not the standard picture. In the literature I refer to, the Big Bang universe is **finite** and expanding, and this is still the basic model. A universe that was formerly large enough for us to see light that was emitted almost 13.8 Gyr ago exists **only** in the supplementary chronogonic model, while the rising $a(t)$ exists **only** in the cosmogonic model. For a rational analysis, these models need to be considered each on its own terms - also for knowing what is meant by "outside" and by

Reviewer's comment: **All of space was brought into existence by the Big Bang.**

Author's continued response: In the cosmogonic model, this is the space above the V-shaped future light cone of the Big Bang in Figure 1. In the chronogonic model, the existing space is that above the abscissa. The reception of radiation from any sources below the golden band in Figure 1 is only compatible with the latter model. If reason is to rule and one accepts this model, one has to reject the Big Bang model (also vice versa).

Reviewer's comment: This is why in co-moving terms photon losses from some region are always (on average) balanced by photons gained from elsewhere. There is also the additional redshifting of photons by which they lose energy individually, but certainly the co-moving number density of photons should remain the same.

Author's response: If it could occur at all, such balancing would **only** be possible in the chronogonic model, while co-moving terms apply **only** in the cosmogonic one, in which this "elsewhere" does not exist. However, the chronogonic model does not give rise to a homogeneous blackbody radiation at all. I think this should be clear from my text, and also that **we** are not in a position within the golden band. To make this clearer, the caption of Figure 1 is now converted from telegraph style into plain English.

Reviewer's comment: In Figure 1, this leads to the author only considering photons emitted from one point on the last scattering surface. In reality, what would be more useful is to

draw two more multiple orange last scattering surface (LSS) cones translated along x , such that they pass through our spacetime location (at the top). The apexes would be where the dotted blue lines intersect with (almost) zero conformal time. This would more accurately represent what happened in the Big Bang according to standard cosmology, and also address the issue of why GN-z11 is currently visible.

Author's response: The golden band in Figure 1 represents all radiation from the LSS in a flat Big Bang universe, i. e. , from **all** points on the LSS. It covers the whole region traversed by the radiation (an expanding shell with a thickness of slightly less than 2 Glyr comoving distance). It is my aim to disclose the deficiency – not to obfuscate it in any way.

Reviewer's comment: It is well known that this does lead to a causality problem in that all these LSS cones have an apex at widely separated points, so shouldn't have been in causal contact even earlier - and thus should have a different temperature. This problem is addressed by the inflationary hypothesis.

Author's response: I remain silent about this well-noted problem, which is caused by the homogeneity of the CMB, allegedly emitted from the LSS, because the models I analyze do not even offer a rational explanation for the very visibility of the LSS.

Reviewer's comment: Another issue is that some sort of confinement is needed to get blackbody radiation, but the author mistakenly assumes that the whole Universe must have some sort of reflective boundary.

Author's response: I consider variations of four models. A reflective boundary is only assumed in model 2, and I judged all four models untenable. However, I **point out** that a non-reflective flat Big Bang universe offers no possibility for us to see the LSS. This follows logically from what we know about the propagation of light and the motion of matter. A chronogonic universe would allow us to see something at otherwise excessive distances, but I point out that it does not give rise to anything like the LSS.

Reviewer's comment: In reality the confinement arises because the early Universe was opaque because neutral hydrogen atoms did not exist yet, and electrons have a large Thomson scattering cross section. So photons had only a short mean free path/travel time between absorptions. This is really the origin of the blackbody spectrum - not the walls of the Universe, which would be more analogous to terrestrial experiments involving a sealed-off room.

Author's response: I did not subject this alleged reality to any criticism at all. My criticism concerns what the model predicts to happen **after** the alleged event of last scattering, which I took as given in my reasoning.

Reviewer's comment: At the end of page 7, the author states without justification that the visibility of high- z galaxies has not been reconciled with a hot Big Bang.

Author's response: It has not been reconciled with a Big Bang since these galaxies are located **outside the space a Big Bang model offers**. I still think I had made this clear

enough on the preceding pages.

Reviewer's comment: There is no problem with this in the standard context - the galaxy would have been relatively close to us, but in an expanding universe, light from it would only just have been able to keep pace with the ever increasing distance remaining to the Earth. Most of the progress would be achieved at late times when the Hubble parameter was lower. The total travel time would be almost 13.8 Gyr. There is nothing unusual about this, in an infinite Universe. The problem with the authors's logic is that a finite Universe is assumed, which would indeed cause very serious problems.

Author's response: It is not the *finiteness* but the former *smallness* of the Big Bang universe that causes the problem. When there is no other way out, the mainstream accepts that the universe was at least as large as it is now (not necessarily infinite) already 13.8 Gyr ago. However, this is blatantly irrational if a Big Bang model, in which the universe was much smaller before, is used and crucial for explaining other aspects of the universe and the CMB.

Reviewer's comment: Although the last part on the sociological aspects is reasonably well done, I strongly recommend the author delete this last bit: but it is, of course, even more fundamental to respect reason at all.

Author's response: To me, this statement appears to the point. I see nothing controversial in it. It expresses the generalized lesson of this article – which admittedly can be hard for the wrongly indoctrinated.

Reviewer's comment: In conclusion, the fundamental assumptions underpinning the article are completely incorrect for the reasons I have explained. Therefore, I still have to recommend rejection of the revised article, and also recommend that in future other reviewers be used in order to get a second opinion. My opinion is that it is not possible to edit the article in such a way that it can ever be approved, since the only novel claim in the article is that all standard cosmologists over the past 80 or so years have made a basic blunder - but it is completely clear to me that the blunder is on the part of the author, who has not understood the most basic aspects of the standard hot Big Bang cosmological model.

Author's response: I am not aware of any accusation that I did not respond to adequately. It is, of course, more reasonable to believe that it is me, an outsider, who has made a blunder than that the whole community of professionals, which includes several Nobel laureates, all could have repeated the same blunder for many decades. However, this is not a physical argument. It is the natural prejudice that I hoped to bypass by submitting my article to F1000Research. I confirm that I have not understood the standard cosmological model, but I claim that nobody else can have understood it either, because it defies rationality.

I would, anyway, like to express my gratitude to Dr Indranil Banik for having accepted the role of a public reviewer of my article at all. His comments have brought me to make several clarifying amendments.

Competing Interests: No competing interests were disclosed.

Version 1

Reviewer Report 29 April 2020

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Indranil Banik

Helmholtz Institute for Radiation and Nuclear Physics (HISKP), University of Bonn, Bonn, Germany

The following article claims to raise serious conceptual problems with the standard cosmological model:

I have to recommend that the article be rejected. First of all, the discussion section is offensive - as a researcher working on non-mainstream ideas, I can understand the sometimes difficult struggle when challenging the mainstream paradigm. But to suggest that I am recommending rejection in order to protect my career is extremely offensive, when my career in fact relies on challenging the mainstream view. The referee might like to know this before dismissing my rejection as a sign of anything other than scientific invalidity of his ideas. But I agree that it is occasionally possible for articles to be rejected which are actually correct, because the referee is protecting personal interests. This is certainly not as common as the author makes out, and indeed I have had generally respectful discussions with mainstream cosmologists despite viewing the Universe very differently. For such a (hopefully) polite discussion, the author may like to watch this debate:

<https://www.eso.org/sci/meetings/2020/Cosmic-Duologues.html>

Regarding the article itself, the main problem is the author has not understood the basics of the Big Bang model in which there is not an explosion in space, but an expansion of space. In this model, the universe is infinite and almost homogeneous at early times. In co-moving co-ordinates, this expansion is cancelled out and you would just see a static Universe. Suppose a flash of light is emitted from every location at the same time. Photons in some region would of course be moving at c , thus leaving through the boundary - but other photons would enter. The number density of photons would thus remain the same in co-moving co-ordinates. There is no inconsistency here. It explains why we expect to measure the same co-moving number density of primordial photons today as there was at the time of last scattering.

Regarding the issue of where the surface of last scattering is, the author should simply consider a photon that has been travelling at c for a Hubble time in a straight line. The result is at some

distance, independent of direction - so the surface is a sphere. However, this is not a real surface - it is just the locus of points from which photons will later hit the Earth exactly 13.8 Gyr later. At the time of emission, nothing whatsoever is special about material in this surface. The whole sphere may well be much larger than 380 kly, which is somewhat non-intuitive since the age of the universe was (in this model) only 380 kyr then.

The author raises an important point about how the Universe was in thermal equilibrium at early times. This is related to the horizon problem, which - as the author points out - is thought to be resolved by inflation. Briefly, the idea is that the Universe was small for an extended period of time, during which it was in causal contact and thus reached thermal equilibrium. The particle horizon then expanded faster than c due to a period of accelerated expansion similar to what we are experiencing now, causing that photons reaching us from different sides of the sky have the same temperature. The author then goes on to unscientifically attack the hypothesis of inflation - indeed, it is well known that this is not confirmed. However, the author does not raise any substantive arguments against the inflation model, and does not propose his own ideas.

Of course, if the mainstream idea was that the Universe was 380 kly wide at some time 13.8 Gyr ago and that every location within it emitted photons at that moment (almost) equally in all directions, then it is clear that these photons would be unobservable now - depending on what happens at the edge. However, the Universe is not thought to have any such edge, and is considered to be infinite. It is certainly the case that light emitted from close to us would no longer be observable, so what we see as the cosmic microwave background (CMB) must have originated rather far away, on the surface of last scattering. The longer we wait, the further away this surface is - though it always corresponds to the same moment in the history of the universe. There will never be a moment when there is no CMB altogether (barring absorption of all its photons), because one can always imagine reversing the arrow of time and integrating a trajectory moving away from us at c in a contracting universe. The photon will have some well-defined location at the moment of last scattering, so this point will be part of the surface of last scattering to such an observer. No special reflective surface is required, and indeed no new assumptions are needed at all to explain the observability of the CMB. Of course, explaining its detailed properties remains a challenge given other constraints e.g. the Hubble tension. But the particular criticism of the standard cosmological model raised by the author is completely erroneous. Therefore, this manuscript must be rejected - even though I do consider that the same is true for the standard cosmological model as a whole, which does indeed contain many hypothetical ingredients that I am not at all a fan of & have publicly spoken against on several occasions e.g. here:

<https://www.youtube.com/watch?v=PYVC0VtmpDg>

Is the topic of the opinion article discussed accurately in the context of the current literature?

Yes

Are all factual statements correct and adequately supported by citations?

No

Are arguments sufficiently supported by evidence from the published literature?

No

Are the conclusions drawn balanced and justified on the basis of the presented arguments?

No

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Modified Newtonian Dynamics (MOND) I felt I was able to assess all aspects of the article, as I work on a non-mainstream cosmological model and need to pay close attention to issues like the cosmic microwave background radiation and cosmology, which remains a little uncertain in MOND

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 14 May 2020

Hartmut Trautmüller, Stockholm University, Stockholm, Sweden

Reviewer's comment: I have to recommend that the article be rejected. First of all, the discussion section is offensive - as a researcher working on non-mainstream ideas, I can understand the sometimes difficult struggle when challenging the mainstream paradigm. But to suggest that I am recommending rejection in order to protect my career is extremely offensive, when my career in fact relies on challenging the mainstream view. The referee might like to know this before dismissing my rejection as a sign of anything other than scientific invalidity of his ideas.

Author's response: This review (there is no separate referee) emphasizes something other on the preceding lines. It has probably to do with my mentioning, in the next to last passage of the article, of a good reason *editors* might have for rejecting certain manuscripts prior to review. In the same passage, I suggest a milder, equally rational explanation - one that applies beside editors also to *reviewers* and definitely also to myself in many analogous situations.

Reviewer's comment: But I agree that it is occasionally possible for articles to be rejected which are actually correct, because the referee is protecting personal interests. This is certainly not as common as the author makes out,

Author's response: This is common in certain cases, also self-censorship. To make it clear in which cases, I have inserted a reference to Lakatos, who had observed that the "hard core" of "research programmes" (such as mainstream cosmology) is beyond criticism.

Reviewer's comment: the main problem is the author has not understood the basics of the Big Bang model in which there is not an explosion in space, but an expansion of space.

Author's response: In the next to last passage of the *Introduction*, in which I summarize the characteristics of a Big Bang model that are essential here, I told that the expansion uses to be ascribed to "space", i.e., to an expansion *of* space. An expansion *in* space was nowhere

implied, but at the end of the second passage under *Model 4*, I have now inserted a parenthetical phrase “or at least empty” after “non-existent” only for telling that this related distinction makes no difference in this context.

Author's response to the Reviewer's remaining comments: These have brought me to underline the fact that, in a Big Bang universe, it is not the case that blackbody radiation lost from a region is balanced by an equal amount gained from outside and, above all, to extend the description and analysis of the present standard model (new text under *Model 4*) as summarized in the "Update text". I kindly ask the reviewer for a new evaluation.

Competing Interests: No competing interests were disclosed.

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