Does standard cosmology predict the CMB?

Does standard cosmology predict the cosmic microwave background?

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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 travels faster than matter can move, one can ask how we, made of matter from this very source, can still see the light. Here, it is shown that radiation emitted by any source earlier than half the “conformal age” of the universe, < 1.7 billion years after the Big Bang, also by distant galaxies, can only become visible via an adequately mirrored or curved return path. The latter is possible in spatially closed, balloon-like models. However, there is no reflector in standard cosmology, and observations suggest the universe to be “flat” rather than balloon-like. Although often advanced as evidence for a hot Big Bang, the CMB actually tells against a formerly smaller universe and so do the most distant galaxies. Origin and retention of the blunder are discussed. Together with additional known deficiencies, it makes a more well-founded cosmology appear overdue.

1. Introduction

In 1964, Penzias and Wilson [1] 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 [2]. Further, based on absorption lines of interstellar CN-molecules, McKellar [3], had suggested a maximum temperature of interstellar space of no more than 2.7 K. In 1948, Alpher and Herman [4, 5, 6], who, like their teacher Gamow [7], were contemplating thermonuclear reactions in the expanding universe, expected a thermal radiation with about 5 K as a residual of a hot Big Bang. In this, Alpher and Herman built on Tolman’s [8] study of model universes filled with blackbody radiation, 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” [5] (p. 327).

When Penzias and Wilson [1] were bothered by the presence of unexpected radiation, another group of scientists (Dicke, Peebles, Roll and Wilkinson) [9] 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.” [9].

Dicke et al. [9] were initially in favour 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
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consistent with the present 3.5° K, we are forced to adopt an open space, with very low density.” [9]. They had expected the temperature to exceed 30 K in a closed space.

The cyclic model lost all support in the late 1990s, when an accelerated expansion suggested itself (within the Big Bang paradigm) in the redshift-magnitude relation of supernovae [10-12]. 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 referred to as “recombination”. Only after recombination, 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, [13] when it had cooled to about 3000 K. The thermal radiation is said to have been emitted from a “last scattering surface” and to have retained its blackbody spectrum because it expanded adiabatically. Due to the ever continuing expansion of “space”, rather than of the universe, 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 [14], while the temperature decreased to the present 2.7 K.

Tolman [8] had calculated the thermodynamic effects of changes in the volume of hollow enclosures that are completely filled with radiation in thermal equilibrium with their walls, which is the characteristic environment of blackbody radiation. Neither Tolman nor his followers seem to have raised the questions of what constitutes the confinement, i.e., the “walls” of an expanding universe and which difference its motion as such and its absence would make. The conditions assumed by Tolman [8] and presupposed by his followers require a confinement of variable but restricted size. The problem disclosed in the following stems from neglecting this.

2. The Problem

Since the 1970s, the presence of the CMB has routinely been advanced as the strongest piece of evidence for a hot Big Bang. Although the account related in the passage before the previous one has become the established doctrine, it raises a nagging question:

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 speed for 13.7 \(10^9\) years, and the matter of which we consist escaped from the same region at a lower speed, then, how can it be that we are ahead of the light?

The visibility of the CMB may immediately strike one as incompatible with the stated premises. The ‘flash’ of light from the last scattering surface had a substantial duration, but it must have passed our place very long ago. It could only be visible to us if the light had taken a forward and return path of the right length. In a model, this path would need to be specified.

Before turning to the standard model, which will be shown to be inconsistent, let us first briefly consider three major alternatives, which also lack support for various reasons.

1) 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 last scattering surface can be visible, at least intermittently, because these models allow a return path of light. However, analyses of high resolution maps of the CMB were found to be compatible with a flat universe [15, 16] rather than with a positively curved one. This unpredicted flatness poses a
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“coincidence problem” \[17\], but the flat universe was subsequently adopted as the standard. Since the predictions of standard cosmology are in focus here, we can leave the curved universes without further consideration.

2) In a “flat” Big Bang model (curvature 0) with no edge or wall around it, light will escape from the expanding material universe and proceed farther at \(c\). The material universe will be surrounded by an expanding region that contains radiation, perhaps including cosmic rays, but no ordinary matter. In such a universe, the last scattering surface will no longer be visible when more time had passed than what light needed for crossing the universe when it had become transparent (the vertical width of the gray bands in Figure 1). Since this happened long ago, the CMB we see now could not have originated there. In such a universe, the conditions assumed by Tolman \[8\] and presupposed by his followers are not permanently retained after last scattering, since this would require the radiation to fill all of space - not only the space represented by the gray bands in Figure 1.

3) In a flat Big Bang universe with an edge, light can be reflected there. Complete reflection occurs if the impedance of space becomes infinite or zero at the edge. The impedance actually becomes undefined, but it may be more problematic that, in order for the CMB to become visible, the reflection must occur where our past light cone crosses the future light cone of the last scattering surface, which is mostly closer to us than the utmost edge. An elaborate model that describes this or a view via repetitive reflections at opposite edges (also illustrated in Figure 1), does not appear to have been proposed.

4) The present standard model \[13, 18\] is a disguised variant of alternative 2), in which the universe is flat, has no edge, and it is simply stated that the source of the CMB, the last scattering surface, is the set of points from which it takes a photon \(13.7 \times 10^9\) years to reach us. This is, however, distinctly problematic because a flat Big Bang universe in which no reflection occurs contains no points from which it would take so much time. The points of origin appear to be located outside the space that was brought into existence by the Big Bang. They are about \(±45.7\) Gyr farther away in comoving distance than the surface at which the CMB photons are assumed to have been last scattered, at \(t = 380\) kyr. In terms of comoving distance, the extension of this surface had then already grown to almost \(±1\) Gyr, but no more. The respective places are marked in Figure 1, in which “conformal time” (presently \(η = 46.7\) Gyr) and “comoving distance” (in Gyr) are used as coordinates in order to depict, without distortion, the theoretical effects the expansion of the Big Bang universe has. These coordinates restore constant light cone slopes of \(±1\) lyr/yr.

Figure 1 illustrates also the wider relevance of the problem: 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 \(η = 23.35\) Gyr). This corresponds to \(t = 1.7\) 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 implicitly requires light to take a forward and return path in comoving distance. This has gone largely unnoticed. About galaxies, such as GN-z11, with redshift \(z = 11.09\), it is reported that “This indicates that this galaxy lies at only \(~400 Myr after the Big Bang\)” \[19\], at \(a(t) \approx 0.083\). This puts the galaxy 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 everything, at origo in Figure 1. This self-contradiction went unnoticed, although the first galaxy that, with \(z = 3.8\), was too far away to be seen directly had been observed already in 1987 \[20\]. On the other hand, a different “horizon
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problem” [17, 18], namely that the CMB is very isotropic although different regions of it would never have been in causal contact, has often been mentioned, and it has also been reported that galaxies at \( z > 4 \) do not show the evolution they should according to the hierarchical merging paradigm that has become part of concordance cosmology [21].

The statement that it takes a CMB photon \( 13.7 \times 10^9 \) years to reach us here and now is just an estimate of the time that has elapsed since its emission. While CMB photons may actually require this much time, or even more, to reach us from their source, a flat and reflection-free Big Bang model does not provide the spacetime that would be necessary in order to accommodate a ray, i.e., a geodesic, of the corresponding length. If such a ray is to end at us, it must have its origin outside the Big Bang universe. This is in contradiction to the reasoning about the properties of the CMB (in the last passage of the introduction), which presumes an origin inside it. Standard cosmology is self-contradictory on this point.

In stark contrast to what is traditionally claimed, the CMB actually tells against a formerly smaller universe and so do the most distant galaxies. Their visibility falsifies the idea of a Big Bang. As for the CMB, the contradiction might disappear if we actually saw mirror images [as in alternative 3)], but in order for galaxies to be seen in this way, the necessary reflector would have to be of all too spectacular stability and near-flatness - like that in a telescope that is giga-lightyears in length.

3. Discussion

Because of the inherent inconsistency of the standard ΛCDM concordance cosmology, here represented by alternative 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 and Lineweaver [22]. These authors deserve credit for having corrected several of those. However, they did not either notice that early events cannot be seen directly. In proceeding without considering reflections (last passage of section 3.3), they mistook the intersection between our past light cone and the future light cone of the CMB [where a reflection would need to occur] for “the points from which the CMB was emitted” [22] (p. 101). Although this is right on rather than beyond the future light cone of the Big Bang, it would still be off target by half as much as alternative 4). The confusion arose by equating the “particle horizon”, which keeps the observable universe within the future light cone of the Big Bang, with the surface of last scattering, which the authors refer to as “our effective particle horizon” [22] (p. 101). It also disagrees with the caption of their Figure 1, which presupposes alternative 4) as such.

Where are the historical roots of the problem? Although Tolman [8] described the nature of blackbody radiation in detail, i.e., of the Hohlraumstrahlung ‘cavity radiation’ of Stefan and Boltzmann, he did not tell what constitutes the cavity wall that must be there if the radiation is to be confined in the universe as blackbody radiation, and which difference the absence of a reflective confinement or ‘edge’ of the universe, would make. This is crucial and basically very simple: if there is no confinement or if there is one that recedes at \( c \), any radiation will escape to infinity and so disappear from view. In a flat and unbounded Big Bang universe [alternative 2) above], this is bound to happen to the radiation from the last scattering surface. This radiation (CMB) is, thus, predicted not to be visible.

The fact that the inconsistency has been missed is, fundamentally, an instance of the ordinary uncritical transfer of human culture, of traditions and doctrines from seniors to juniors, which also has given rise to an abundance of languages, belief systems and mythologies. In this cultural environment, science stands out as an exceptional, more global and, crucially, a more critical endeavor that requires practitioners not simply to accept and adopt what they were
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taught, but to check the assumptions and doctrines relied on for consistency and tenability. The fact that this has not happened in the present case raises, at least, the question of why the inconsistency has been missed even by researchers with a critical attitude. The following two factors may have contributed:

Firstly, it may happen that questions like the one at the beginning of section 2, which might be asked by children, are dismissed as too childish to deserve any attention. Although self-confident adherents of the traditional doctrine run a higher risk for this, even adherents of alternative models may consider it too unlikely for the whole collective of mainstream cosmologists to have committed a cardinal blunder like the one here disclosed.

Secondly, even to less prejudiced people, spacetime diagrams with the ordinary coordinates of time and distance can be misleading and hide the inconsistency, especially if they show a past light cone (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 and Lineweaver [22], more detailed in [23] and without any scale in [24].

Although the deficiency disclosed here can be judged as worse, other ones need to be amended as well [25-29]. Just consider that both \( \Lambda \) (dark energy) and CDM (cold dark matter) have remained in the imaginary realm and so represent mere conventions introduced in order to protect a doctrine from empirical falsification [28, 29]. These facts disclose the protective entities as mythological ones. This approach is at least excessively speculative, and logical inconsistencies such as the one revealed here must be rejected in any discipline that is meant to qualify as rational. In order to progress, one should also eliminate any additional old blunders before and instead of suggesting some fancy new physics that might hide them. It would, in general, be more prudent to strive for well-foundedness in the physical principles [29] than merely for a rationalized mythology, but it is, of course, even more fundamental to respect rationality.
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References


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**Figure 1: Spacetime diagram of the flat Big Bang universe.**

The V-like pattern shows the future light cones of the Big Bang (BB, black line) and of any events on the last scattering surface (LSS, blue horizontal dash and grey V-like band). Note that this surface, the supposed origin of the CMB, is visible directly only from positions within the grey band. We are not there, but at the peak of the Λ-like trace (full red line), which shows our past light cone. Everything that is now visible to us is on this past light cone, which ends where it hits the future light cone of the Big Bang. The region beyond (dotted extension) has not come into existence. In alternative 4), the galaxy GN-z11 and peripheral ghost images of the LSS are placed in this region nevertheless (at around ±46 Gyr comoving distance). A path from the original LSS to us via repetitive reflections at opposite retracted edges of the universe is shown in principle only (dashed line). For the dotted horizontal lines see Table 1. Last scattering at conformal time $\eta \approx 0.95$ Gyr, $t \approx 0.38$ Myr; last visibility of the LSS and last blackbody conditions at $\eta \approx 1.9$ Gyr, $t \approx 1.95$ Myr.

**Table 1:** The values of scale factor $a$, redshift $z$ and age $t$ of the universe, listed for the conformal times $\eta$ represented by the dotted horizontal lines in Figure 1. Values based on 5-year WMAP data and ΛCDM model computed using WolframAlpha®.