Does standard cosmology predict the CMB?

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Abstract
In standard Big Bang cosmology, the universe expanded from a very dense and opaque initial state. The light that was emitted about 380,000 years later, when the universe became 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 from its source faster than matter can move, it is prudent to ask how we, made of matter from this very source, can see it nevertheless. 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, requires special conditions in order to become visible. It would need to be mirrored back to us or take a curved return path, which it can in spatially closed, balloon-like models. However, there is no mirror in standard cosmology, and observations suggest the universe to be “flat” rather than balloon-like. The approach appears inapt for predicting the CMB and making sense of large redshifts. This tops other deficiencies and makes a more well-founded cosmology appear overdue.

Keywords: cosmic microwave background; cosmology: theory; cosmology: observations

1. Introduction
Prior to the serendipitous discovery of the cosmic microwave background (CMB) (Penzias & Wilson, 1965), the presence of a cosmic heat bath with a temperature of a few K had already been conjectured by several researchers on various grounds (Assis & Neves, 1995). Gamow and his collaborators (Alpher & Herman, 1948, 1975), who were interested in thermonuclear reactions in the expanding universe, expected it as a relic radiation of a hot big bang. In this, they built on Tolman’s (1934) considerations of a model universe filled with blackbody radiation. In these, the big bang universe was considered as a hollow enclosure that is completely filled with radiation in thermal equilibrium with its walls, which is characteristic of blackbody radiation. The question of what constitutes the reflective walls or their equivalent in the expanding universe was not really treated.

When Penzias and Wilson (1965) were bothered by the presence of unexpected radiation, another group of scientists, in the tradition of Tolman (1934) and Alpher & Herman (1948), did expect it in a hot big bang model and was developing an experiment in order to measure it. They (Dicke et al., 1965) considered it “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.” They continued: “The presence of thermal radiation remaining from the fireball is to be expected if we can trace the expansion of the universe back to a time when the temperature was of the order of $10^{10}$ °K, in order that the ashes of the previous cycle would have been reprocessed back to the hydrogen required for the stars in the next cycle.” They attached nonexclusive preference to 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.
In the late 1990s, when the opposite of the expected slow down in the apparent expansion of the universe suggested itself in the redshift-magnitude relation of supernovae (Perlmutter, 2012; Schmidt, 2012; Riess, 2012), the cyclic model lost support. In subsequent versions of big bang cosmology, 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” – a term that was to the point in cyclic universe models. 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, (Smoot, 2007) 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 (Bennett et al., 2003), while the temperature decreased to the present 2.7 K.

2. The Problem

Although widely accepted, the described account raises a nagging question:

If the CMB originated at the last scattering surface
and all matter originated within the region encircled by this surface,
while light escaped from there at \( c = 300 000 \text{ km/s} \), maintaining this speed for \( 13.7 \times 10^9 \) years,
and the matter of which we consist escaped from the same region at a much lower speed,
then, how can it be that the light (CMB) has not passed us (our galaxy) very long ago?

The visibility of the CMB may immediately strike one as incompatible with the stated premises, but there would be a way out if the light had taken a forward and return path of the right length. However, this path would need to be specified. Before turning to the standard model, which will be shown to be self-contradictory, let us first consider three major alternatives, which 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 remains visible. These models used to be popular because they allow a return path of light. However, analyses of high resolution maps of the CMB were found to be compatible with a flat universe (de Bernardis et al., 2000; Davis et al. 2007) rather than with a positively curved one. This unpredicted flatness poses a “coincidence problem” (Debono & Smoot, 2016), 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 presupposed by Tolman (1934) and 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. Adiabaticity of the expansion is not a sufficient condition.

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 CMB, which is mostly closer to us than the utmost edge. A 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 (Smoot, 2007; Ryden, 2016) 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 alleged points of origin are located outside the space that was brought into existence by the big bang. They are about $\pm 45.7$ 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 $\pm 1$ Gyr, but no more. The respective places are marked in Figure 1, in which “conformal time” (presently $\eta = 46.7$ 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 $\pm 1$ 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 $\eta = 23.35$ Gyr). This corresponds to $t = 1.7$ Gyr and redshift $z = 3.76$. 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 $\sim 400$ Myr after the Big Bang” (Oesh et al., 2016), at $a(t) \approx 0.083$. This puts the galaxy, with $z > 3.76$, beyond the “particle horizon”, which is the future light cone of the big bang. If anything exists in this spacetime region, it cannot be traced back to the presumed ultimate origin of everything. Astonishingly, no attention has been paid to this self-contradiction. On the other hand, a different “horizon problem” (Debono & Smoot, 2016; Ryden, 2016), namely that the CMB is very isotropic although different regions of it would never have been in causal contact, has often been considered.

The statement that it takes a CMB photon $13.7 \times 10^9$ years to reach us here and now is not the result of a calculation based on the path that the photon will follow from the last scattering surface to the observer in the standard model, but only an estimate of the time that has elapsed between the events. While this estimate, with moderate variation in the quantity, is likely to hold in any tenable model, a flat and reflection-free big bang model does not provide the necessary spacetime for it.
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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, grey band above). 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 top of the Λ-like pattern (full red line), which shows our past light cone. Everything that is now visible to us is within this past light cone, which ends where it hits the future big bang light cone. The region beyond (dotted red extension) has not come into existence. Comoving distance and conformal time are not properly defined there. In alternative 4), the galaxy GN-z11 and a peripheral version of the LSS are placed therein nevertheless. A path from the original version 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 $\eta \approx 0.95 \text{ Gyr}, t \approx 0.38 \text{ Myr}$; last visibility of the LSS and last blackbody conditions at $\eta \approx 1.9 \text{ Gyr}, t \approx 1.95 \text{ Myr}.$

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 $\Lambda$CDM model computed using WolframAlpha$^{SM}$.

<table>
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<tr>
<th>Conformal time $\eta$ (Gyr)</th>
<th>$a$</th>
<th>$z$</th>
<th>$t$ (Gyr)</th>
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</tr>
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3. Discussion

The standard model is evidently misconceived. Misconceptions and confusions have long been common in papers on cosmology, also in many by renowned authors. Davis & Lineweaver (2004) deserve credit for having corrected several of these. 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” (p. 101). Although this would be on the right side of the particle horizon, 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” (Davis & Lineweaver, 2004). It also disagrees with the caption of their Figure 1, which presupposes alternative 4) as such.

The standard ΛCDM concordance cosmology, represented by alternative 4), must be rejected because it is irrational. In stark contrast to what is traditionally claimed, it fails to predict the CMB to be visible. It contradicts itself when confronted with large cosmic redshifts. Why has this been missed even by people with a critical attitude? Here, it shall only be noted, firstly, that questions like the one at the beginning of section 2, which might be asked by children, may evoke an improper attitude in self-confident adherents of the traditional doctrine and, secondly, that spacetime diagrams with the ordinary coordinates of time and distance are often misleading, namely 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 & Lineweaver (2004), more detailed in Whittle (2006) and without any scale in Wright (2018).

As for the CMB, the contradiction might disappear if we actually saw mirror images, but for galaxies to be seen in this way, the mirror that would surround the universe would have to be of spectacular stability and near-flatness. Further, even a small gravitational deflection could grossly distort the picture.

It would not either be satisfactory to rationalize the theory on this point alone. Although the deficiency disclosed here can be judged as worse, other ones need to be amended as well (Traunmüller, 2014; Spergel, 2015; López-Colrredoir, 2017; Merritt, 2017; Traunmüller, 2018). Just consider that both Λ (dark energy) and CDM (cold dark matter) have remained in the imaginary realm and so stand out as mere conventions introduced in order to protect a doctrine from empirical falsification (Merritt, 2017; Traunmüller, 2018). This approach identifies the protective entities as mythological ones. Within physics, it would be more prudent to strive for well-foundedness in its principles (Traunmüller, 2018) than for a more rational mythology.
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References


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