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The Cosmic Microwave Background Radiation Does NOT Prove that the Hot Big Bang Theory Is Correct

Bernard R. Bligh

4, St. James's Avenue, Hampton Hill, Middlesex, TW12 1HH, UK
email: brbligh@hotmail.com

Abstract. It has frequently been asserted that the discovery of the Cosmic Microwave Background Radiation (CMB) by Penzias and Wilson is proof of the validity of the Hot Big Bang Theory of the origin of the Universe. In reality this is not the case because the expansion of the Universe at the time of the supposed "Fireball" would not produce the perfect black-body radiation which is actually observed. This problem with the CMB has been pointed out before by Mitchell (1994) but the present study establishes the argument by means of rigorous thermodynamic calculations.

The CMB is said to have been produced at the time of"de-coupling" when the electron density in the primeval Universe was very small. The radiation generated at that epoch would have had a black-body spectrum. Three cases are analysed when the electron density approached zero; three appropriate temperatures are taken and then the thermodynamic properties — including density — are calculated for the three cases. These provide a measure of the expansion to the present day. Wien's law is applied to calculate the fall in temperature of the radiation for each case — assuming that the black-body spectrum is maintained. According to the Hot Big Bang Theory the three cases should all arrive at 2.72 K, but they do not. The conclusion is that the CMB spectrum ought to be "smeared" and not the almost perfect black-body curve, which is actually observed. Therefore the Hot Big Bang Theory fails this test.

1. Introduction

When a scientist embarks on the design of a piece of equipment such as a gas liquefier, he/she first needs to assemble the thermodynamic properties of the gas, i.e. specific heat capacity, enthalpy, entropy, latent heat, vapour pressure, thermal conductivity, viscosity, etc. This information is employed to do accurate calculations. Without such calculations the design would not be valid. The same approach is necessary for the Hot Big Bang Theory, but hitherto such rigorous thermodynamic calculations have not been applied to that theory.

The main thrust of this paper is that Thermodynamics is an essential feature for a theory to be valid, it is not an optional extra.

We need to put this study of the Cosmic Microwave Background Radiation on a firm footing (CMB). The Hot Big Bang Theorists assert that the primeval Universe was very hot and that it cooled on expansion. Temperature is a thermodynamic property and therefore we must link this with the other thermodynamic properties, namely pressure, density, enthalpy, internal energy, entropy and energy of ionization. For the sake of simplicity it is assumed that the early Universe was all hydrogen.

To establish the case — one way or the other — requires a detailed study of the thermodynamic properties of the plasma when it supposedly passed through a state of "de-coupling" and the matter went from being opaque to being transparent. To quote Mather (1986)

"The electrons of the primeval plasma attach themselves permanently to atomic nuclei and form complete atoms. After this event the electrons could no longer collide frequently with photons — the Universe became abruptly transparent to radiation. The CMB is said to be derived from this epoch."

The reasoning presented here analyses the thermodynamic state of matter (according to the theory) when the degree of ionization was a small fraction. It is deduced that the resulting radiation would not have a black body spectrum, but a smeared spectrum. I am not the first person to point this out; Mitchell (1994) has done this before me. The substance of this paper is to give the objection a firm thermodynamic basis.

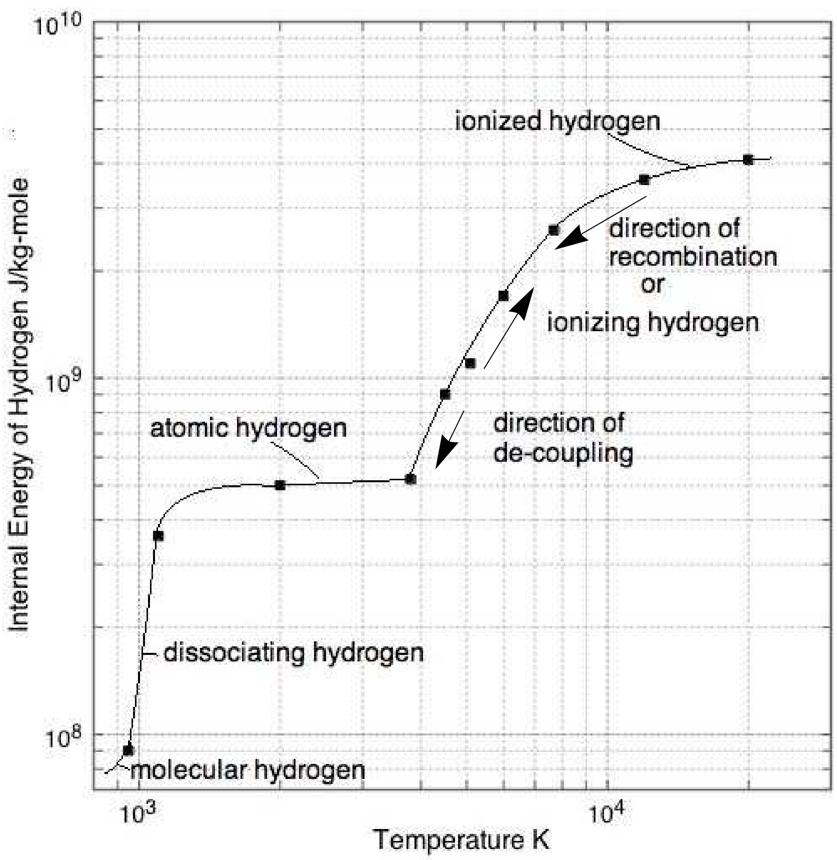

Figure 1. Internal Energy of Hydrogen versus Temperature

2. Thermodynamics

First we must consider the nature of the supposed early Universe. It is believed to have been 93 mole % hydrogen (in Thermodynamics it is molar fractions which are relevant, not mass fractions). We shall make the simplifying assumption that it is all hydrogen.

All data are consistent for one kg-mole of hydrogen,

$$H_2 \Longleftrightarrow 2H \Longleftrightarrow 2H^+ + 2e^-, \tag{1}$$

It is instructive to look at the graph of internal energy of hydrogen versus temperature, Figure 1.

At the top end, the hydrogen is all ionized (20,000 K); as the Universe cooled the hydrogen ions and electrons started to combine to make hydrogen atoms, giving up the ionization energy which is 1,318,000,000 $J\,kg^{-1}\,mole^{-1}$, an enormous number which causes an inflexion in the curve; there is a further inflexion when the atomic hydrogen associates to form hydrogen molecules.

If any other two parameters had been plotted, e.g. pressure versus density, pressure versus enthalpy, temperature versus entropy, there would always be severe kinks in the curves. Hence the straight line graph for the cooling of the Universe, as shown in Figure 2, is wrong. Graphs of this kind are shown in papers by Dicke et al. (1965), Alpher & Herman (1975) and in some books on Cosmology. There should be a substantial inflexion below 10,000 K.

A detailed Temperature-Entropy Diagram for hydrogen was published in 2000 (Bligh 2000) showing the entropy in $kJ\,kg^{-1}\,mole^{-1}\,K^{-1}$ versus temperature K. The diagram contains a wealth of thermodynamic data, particularly the inflexions in the isobars due to the dissociation and ionization of hydrogen. One reason why the diagram is so important is that every point uniquely describes that state of hydrogen. As hydrogen cools from one condition to another, it traces a path on this diagram. The proponents of the Hot Big Bang Theory say that the Universe cooled at constant Entropy. This is a mistake, but that is the "received wisdom." This path would be a vertical line on the Temperature-Entropy Diagram.

We are concerned here with the zone at which the de-coupling is supposed to have happened and we trace the path on this section of the Temperature-Entropy Diagram. Alpher & Herman (1975) state that at one second after the Big Bang the temperature was 10^{10} K.

Figure 3 is a section of the Temperature-Entropy Diagram which relates to the tail end of de-coupling. Three temperatures are considered, which span this tail end, i.e. the period when the electron concentration was very small and when the CMB is supposed to have been generated.

These three states all have the same entropy, 929 $kJ\,kg^{-1}\,mole^{-1}\,K^{-1}$; this conforms to the statements by S. Weinberg, P.C.W. Davies, M. Longair [(Weinberg 1972); (Davies 1974); (Longair 1991)] and other cosmologists that the expansion of the Universe is isentropic.

The "estimated current temperature" means the temperature of the black-body spectrum which ought to have been produced from the initial temperature.

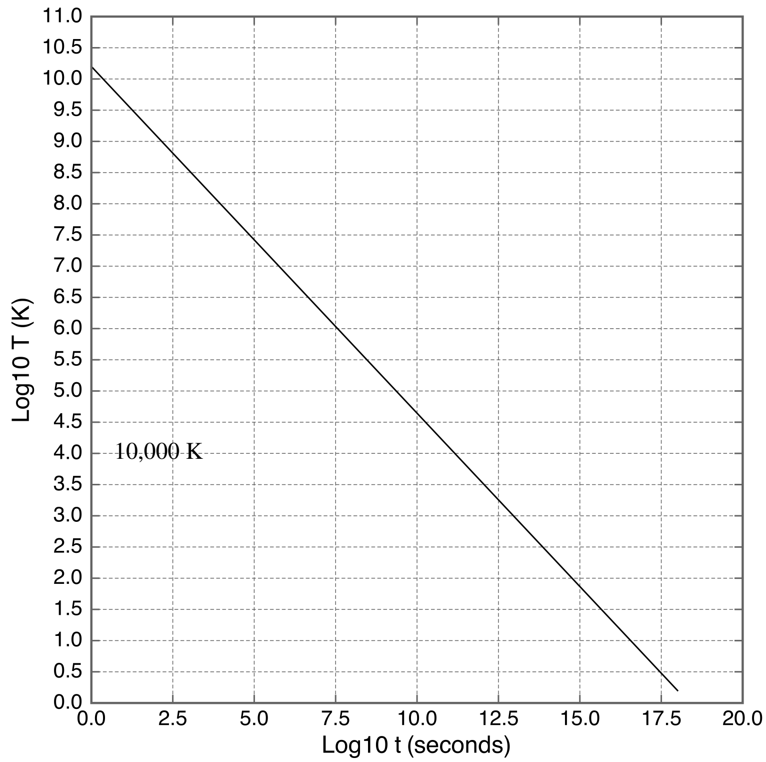

Figure 2. The cooling of the Universe as postulated by some cosmologists; the straight line below 10,000 K is thermodynamically unsound.

Table 1. Results of Thermodynamic Calculations

State	Temp. [K]	Press. $x10^{-10}$ [Pa.]	x fraction ionized	Volume $x10^{17}$ [m^3 per kg-mole]	Scaling factor $V^{1/3}$ [m per kg-mole]	Density $x10^{-17}$ [kg m^{-3}]	Est. current temp T_0 [K]
1	3468	3	0.0359	1.99	5.84×10^5	1.01	2.02
2	3300	1	0.0179	5.59	8.24×10^5	0.361	2.72
3	2850	0.3	0.00056	15.81	1.156×10^6	0.128	3.29

The explanation of these results is as follows. Cosmologists give a range of estimates for the density of the present Universe (Peebles 1968) but a middle value is

$$2 \times 10^{-30} g\, cm^{-3} = 2 \times 10^{-27} kg\, m^{-3}, \tag{2}$$

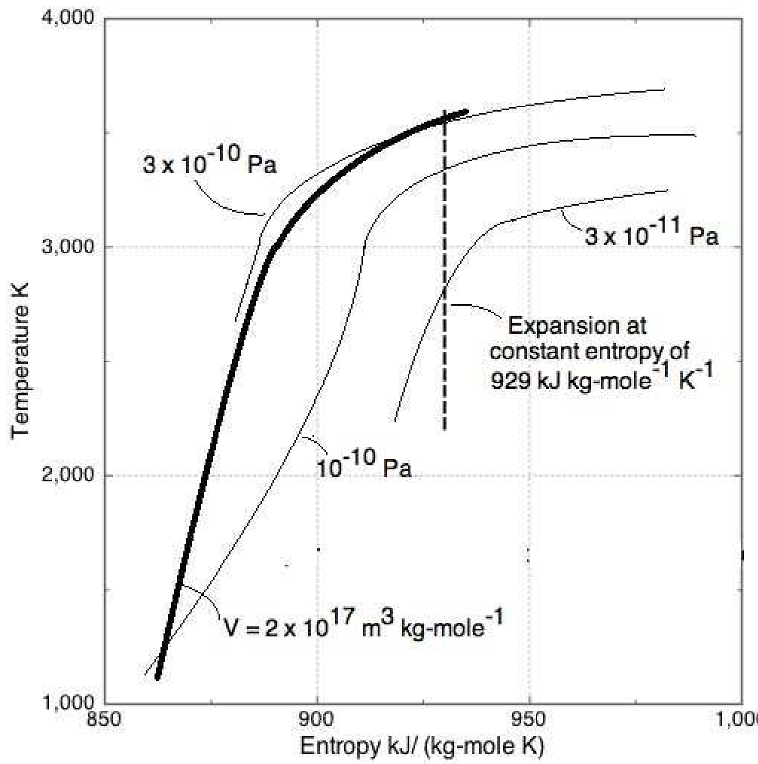

Figure 3. Section of the Temperature vs. Entropy diagram for Hydrogen

this is equivalent to a volume of 10^{27} $m^3\,kg^{-1}mole^{-1}$. We use a model in which we consider the Universe to be a matrix of expanding cubes, in which case a notional kg-mole of hydrogen is now in a cube, side 10^9 m.

The side of a cube containing one kg-mole is a measure of the"scaling factor" of the Universe.

Therefore state [1] has expanded by $10^9/(5.84 \text{ x } 10^5) = 1712$.

We apply Wien's Law, this expansion shifts the peak of the wave-length of the "black-body spectrum" by a factor of 1712 and this gives an apparent temperature of the present black-body spectrum as $3468/1712 = 2.02$ K.

Note that state [2] has the "Estimated Current Temperature" = 2.72 K which is the temperature for the black-body spectrum actually observed. This demonstrates that the calculations have a firm basis in terms of the Hot Big Bang Theory. That is to say, according to "received wisdom" the "fireball" which generated the microwave background radiation must have had thermodynamic properties very close to state [2].

3. Discussion

Now in the theory it is reasonable to assume that the operation of de-coupling took place over a period of time (Lepp & Stancil (1998) give a time in the order of 100,000 years, and Weinberg (2008) does the same in his latest book *Cosmology*) that is to say, as the primeval Universe went from being opaque to being transparent there was a range of conditions of being partially transparent. States [1] and [3] were chosen as being typical borderline cases, which would also generate some of the microwave background, but these would have the appearance of a black-body curve for 2.02 K and 3.29 K respectively. Therefore we should expect the microwave background to be NOT a perfect black-body curve for 2.7 K, but a SMEARED or COMPOSITE curve.

The measured results from the COBE satellite [Mather et al. (1994); Fixsen et al. (1994)] give a microwave background for a PERFECT 2.7 K CURVE; this perfect black-body curve is not what we should expect from the thermodynamic analysis. Therefore these COBE results, far from confirming the Hot Big Bang Theory, provide strong evidence AGAINST the Hot Big Bang Theory.

Now this finding is open to the criticism that I have chosen a set of parameters that suit my argument. It might be possible to select a path of the expanding Universe across the Temperature-Entropy Diagram such that the current temperature of the Microwave Background always works out as 2.7 K — and in fact in Weinberg's latest book, *Cosmology*, that is what he has achieved in his Table 2.2. This book came out in 2008 after I prepared this paper.

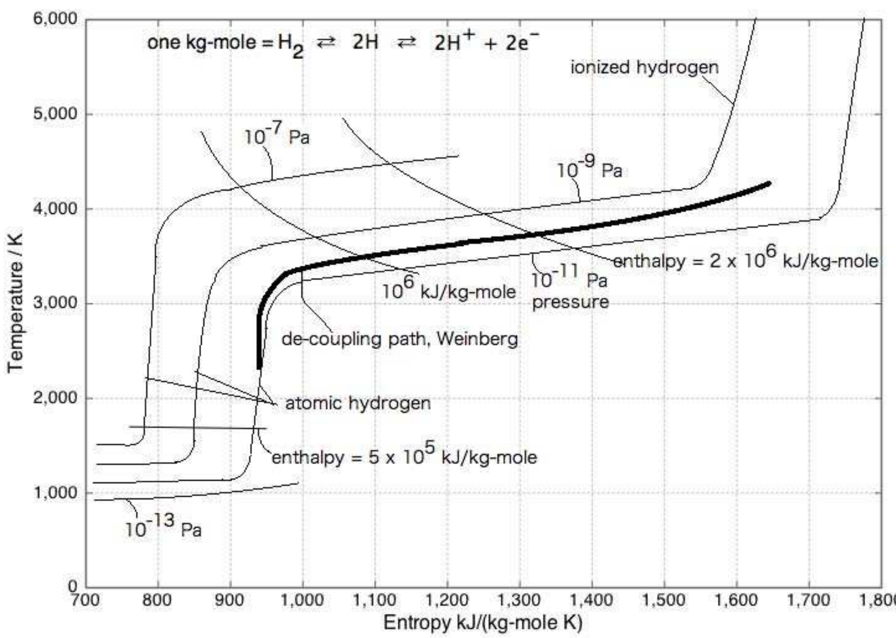

Figure 4. A section of the Temperature-Entropy diagram for hydrogen showing the de-coupling path according to Weinberg; this is contrary to the Second Law of Thermodynamics.

Weinberg makes the simplifying assumption that the Universe consists of hydrogen only (the same as I have done). He presents in Table 2.2 twenty temperatures of a Universe cooling from 4226 K to 100 K as z decreases, and dividing T by z gives a value of 2.72 K in every case.

Weinberg has neglected to calculate the other thermodynamic parameters, namely volume per kg-mole, pressure and Entropy. I have done these calculations and plotted them on a Temperature-Entropy Diagram, Figure 4. His values of Entropy show a considerable decrease over time which is contrary to the Second Law of Thermodynamics and this feature is also inconsistent with his own statement earlier in the same chapter that Entropy remains constant (page 109).

Another criticism of his data is that he shows some degree of ionization down to 600 K; this is incorrect; hydrogen is completely associated into atoms or molecules below 2800 K. It is concluded that Weinberg's assessment of the supposed de-coupling epoch is unsound.

In a nutshell, it is necessary to do rigorous thermodynamic calculations as presented in the Table in order to obtain the correct results. It is impossible to do these calculations without a Temperature-Entropy Diagram or its equivalent. Thermodynamics is not an optional extra, it is an essential feature of any valid theory.

These calculations show that at this hypothetical epoch of electron decoupling, the radiation would NOT lead to the present CMB which has a perfect black-body spectrum.

4. Question Session Response

During Question Time, it was asked whether one could be sure that the thermodynamic approach was valid in Cosmology.

Reply: We start by asking the question "What is temperature?" Temperature is a thermodynamic property which is measured with a thermometer, just as length is measured by measuring rods and time is measured by a clock. It should also be noted that degrees Kelvin are one of the six fundamental units in Physics, that is to say, degrees Kelvin are not dependent on any other units.

But strictly speaking, temperature is measured by a Carnot heat cycle, and indeed, in Low Temperature Physics below one degree Kelvin that is what we do, we put a sample of a paramagnetic salt through a Carnot cycle. I mention this in passing to emphasize that this reasoning is based on good practical Science.

It can be proved by means of the Carnot Theorem that temperatures measured by a Carnot cycle are identical with temperatures measured with the ideal gas thermometer — and if that were not so, a substantial proportion of physics and chemistry would be invalid!

But the Carnot cycle and the Carnot Theorem depend on the First and Second Laws of Thermodynamics for their validity. Therefore cosmologists cannot make statements about temperature like "A few seconds after the Big Bang the temperature of the Universe was 10 billion degrees Kelvin" unless they accede to the Laws of Thermodynamics.

I put it to my critics that this argument is unassailable, and as I said above, it is based on good sound science. Therefore if a theory is postulated which contravenes the Laws of Thermodynamics, cosmologists cannot wriggle out of this fallacy by pleading that Thermodynamics is not relevant to the theory.

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