On the Origins of the CMB: Insight from the COBE, WMAP, and Relikt-1 Satellites

Pierre-Marie Robitaille
Dept. of Radiology, The Ohio State University, 130 Means Hall, 1654 Upham Drive, Columbus, Ohio 43210, USA
E-mail: robitaille.1@osu.edu

The powerful "Cosmic Microwave Background (CMB)" signal currently associated with the origins of the Universe is examined from a historical perspective and relative to the experimental context in which it was measured. Results from the COBE satellite are reviewed, with particular emphasis on the systematic error observed in determining the CMB temperature. The nature of the microwave signal emanating from the oceans is also discussed. From this analysis, it is demonstrated that it is improper for the COBE team to model the Earth as a 285 K blackbody source. The assignment of temperatures to objects that fail to meet the requirements set forth in Kirchhoff's law constitutes a serious overextension of the laws of thermal emission. Using this evidence, and the general rule that powerful signals are associated with proximal sources, the CMB monopole signal is reassigned to the oceans. In turn, through the analysis of COBE, WMAP, and Relikt-1 data, the dipole signal is attributed to motion through a much weaker microwave field present both at the position of the Earth and at the second Lagrange point.

1 Introduction

More than 40 years have elapsed since Penzias and Wilson first reported the existence of a thermal signal in the microwave region of the electromagnetic spectrum [1]. This measurement of the "Cosmic Microwave Background (CMB)" has been viewed as one of the most important in the history of science. Cosmology is now inextricably linked to its validity. Given this realization, it remains interesting that the logical steps first made by Penzias and Wilson [1] have not come under more considered review.

Penzias and Wilson [1] made the assumption that their signal was thermal in origin and inferred that the source could be treated as an ideal blackbody [2]. Without acknowledging the strict requirements involved in setting a blackbody temperature [2–4], they made recourse to the laws of thermal radiation, obtaining a temperature of 3.5 ± 1.0 K [1]. Although the cosmos can never meet the requirements for enclosure set forth by Kirchhoff [2], Dicke et. al. [5] would ultimately assign the signal to the average temperature of the Universe. Penzias and Wilson were thought to have discovered the "CMB", a powerful signal bathing everything.

The COBE satellite [6–12] provided the most important confirmation of the thermal nature of the "CMB" [1]. This satellite is positioned at an elevation of $\sim$900 km above sea level. COBE also reaffirmed the presence of a dipole signal presumably associated with motion of the local group. The dipole signature had been clearly observed by the Soviet Relikt-1 satellite [13], nearly 10 years earlier. Eventually, the WMAP satellite would affirm the existence of the dipole signal [14–16].

2 COBE and the assignment of temperatures

2.1 The "CMB" monopole

In acquiring the "CMB" signal [1], COBE produced a nearly perfect spectrum [11]. The signal to noise from the FIRAS instrument is exceedingly high. The error bars constitute a small fraction of the linewidth and must be expanded, by a factor of 400, to be visualized [11]. The validity of the absolute temperature was not questioned. The source responsible was thought to be at $\sim$3 K. Soon, the "CMB" became the central experimental proof for the Big Bang [17].

It has always been understood, in communications, that powerful signals imply proximal sources. This practical knowledge was neglected [1, 5]. Yet, concerns should have lingered over the amount of power found in the "CMB" [1, 11]. In addition, the experimental justification, for setting blackbody temperatures, was overlooked. The belief, that blackbody radiation was universal [4], enabled the dismissal of all laboratory experiments relative to its nature [3].

The experimental [3] and theoretical [4] basis of universality has now been brought into question. Blackbody radiation is not universal in nature [4], but, rather, is strictly limited to a physical setting best approached by graphite and soot on Earth [3]. A spectrum, like the "CMB" signal [11], may well appear to be thermal, but the temperature will not be valid unless the requirements set forth in Kirchhoff's experiment are strictly followed [3].

The Planckian equation [18] remains detached from the physical world. Thermal emission is explained mathematically [4], without regard to the physical setting. Blackbody radiation is the only process in physics wherein the setting, transition species, and energy levels are devoid of physical meaning [3, 4]. In large part, this is a result of the erroneous belief in universality [3, 4]. Given universality, temperatures were set without the inconvenience of laboratory constraints.

2.2 The "CMB" dipole

In addition to the "CMB" monopole, the COBE satellite reports a dipole signature associated with motion [7], confirming Relikt-1 findings [13]. The WMAP satellite has also detected this dipole signal [19]. The dipole is thought to reflect a doppler phenomenon associated with motion of the local group. Based on COBE measurements, the dipole has an amplitude of 3.353±0.024 mK in a direction $(l, b) = (264.26° \pm 0.33°, 48.22° \pm 0.13°)$, where l is the Galactic longitude and b, the latitude [15]. A nearly identical value, of 3.346±0.017 mK in a direction $(l, b) = (263.85° \pm 0.1°, 48.25° \pm 0.04°)$, has been reported by the WMAP team [15]. Interestingly, the COBE satellite was able to determine a dipole value both from the DMR and the FIRAS instruments [6, 7]. The WMAP satellite is equipped solely with differential radiometers, and measures the dipole in a manner similar to the DMR on COBE [6, 14].

3 An alternative assignment for the "CMB" signals

3.1 Assignment of the monopole

During flight, the COBE satellite experienced an anomaly. "Most of the occurrences were in the High Frequency Region known as the South Atlantic Anomaly" [8]. Since the anomaly was produced over the Atlantic, it is interesting that the "CMB" results are devoid of interfering oceanic signals. The COBE team describes thermal instabilities when the limb of the Earth appears above the shield of the satellite. Data acquired during such events are discarded, but the COBE shield is not adequate to guard the instrumentation from the effects of being immersed in a scattered oceanic signal.

From the days of Penzias and Wilson [1], the Earth has not been considered as a powerful contaminating source for the "CMB". The COBE team believes that the Earth can be modeled as a circular source of emission, with a radius of ∼61° and a mean temperature of 285 K [9]. All scattering of microwave signals, by the atmosphere, is neglected. Whether the Penzias and Wilson signal [1] is measured from the ground, using balloons, or from COBE, the monopole signature is noticeably clean. However, based on the extent of the oceanic surface, and the known behavior of the oceans in the microwave, it is inappropriate to model the Earth as a 285 K source [21].

Water is a good absorber of microwave power. This forms the basis of practical microwave applications. In addition, submarine communications, at microwave frequencies,

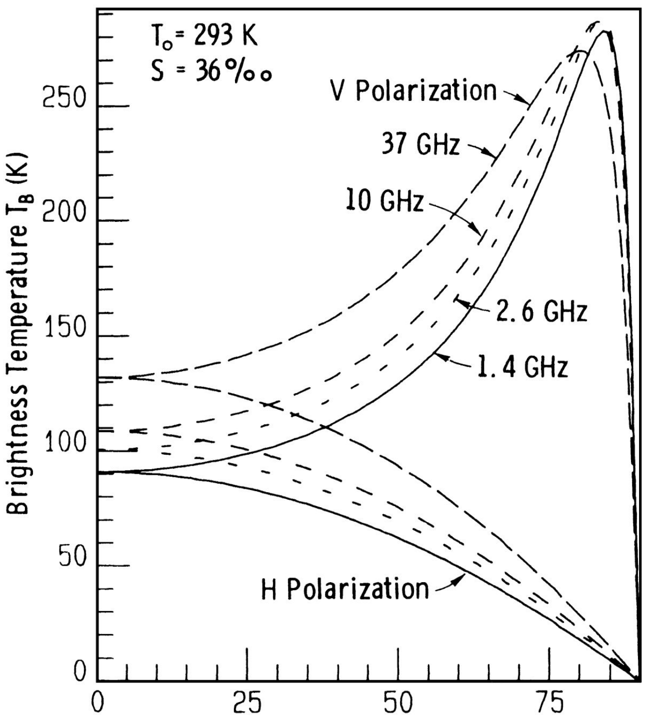

Fig. 1: Brightness temperature of a specular sea surface at 1.4, 2.6, 10, and 37 GHz. Note that when the angle of incidence approaches 90°, the brightness temperature of both the horizontal and vertical components falls to 0 K. As a result, the limb of the Earth appears as a source at nearly 0 K relative to COBE. The assumption that the Earth can be treated as a 285 K source is not valid. Reproduced by permission Figure 11.45 from F. T. Ulaby, R. K. Moore, A. K. Funk. Microwave remote sensing active and passive. — Volume 2: Radar remote sensing and surface scattering emission theory. Norwood (MA), Artech House, Inc., 1982. Copyright by Artech House, Inc., 1982.

are not possible while submerged, indicating powerful absorption. The oceans may be good absorbers of microwave power, but they are certainly not equal emitters. This is because liquids can never be in compliance with Kirchhoff's law [3, 20]. Liquids attempt to reach thermal equilibrium through conduction, thermal radiation, and convection. In fact, Planck has warned that objects, which sustain convection currents, can never be treated as blackbodies [20]. Nonetheless, it is unreasonable to believe that the oceans will be microwave silent on emission [21].

The behavior of oceanic emissions in the microwave is not simple (see Figure 1), depending significantly on the angle of observation [21]. The oceans cannot be treated as a blackbody source simply based on this fact [3]. Note that the brightness temperature of the oceans is dependent on the angle of incidence. Brightness temperatures with a 0° angle of incidence are less than 130 K over the frequency range spanning 1.4–37 GHz. For the vertical polarization, the brightness temperature increases to ∼270 K, as the angle of incidence is raised from 0° to ∼75°. The brightness temperature of the vertical polarization then precipitously drops to 0 K. For the horizontal polarization, the brightness temperature falls gradually from 100 to 0 K, as the incidence angle is increased from 0° to 90°. The situation relative to oceanic emission in the microwave is much more complex than currently assumed by the COBE team [21].

When these facts are combined with atmospheric scattering, concerns linger that the measured "CMB" signal is devoid of Earthly interference. It would have been reassuring if the "CMB" experiments were being contaminated by an oceanic signal whose contributions could not be easily suppressed. Yet, the Penzias and Wilson signal [1, 11] was devoid of external interference. Conversely, oceanographic studies reveal that the seas can produce signals with a brightness temperature near 0 K, as demonstrated in Figure 1. Given the power observed in the monopole [1, 11], it is reasonable that the oceans cannot produce interference in the measurements since, in reality, *they constitute the source of the "CMB"* [22–25].

3.2 Assignment of the dipole

It is currently believed that the dipole signal is being produced by motion of the Relikt-1, COBE, or WMAP satellites through a powerful "CMB" monopole field ascribed to the Universe. However, a second situation exists. The satellites could be flowing through a field much weaker than that detected on Earth. In this scenario, the strong monopole field detected on Earth does not exist at the position of WMAP [59]. Using the data available, it should be possible to distinguish between these two alternatives.

3.3 Absolute measurements and error bars in the COBE satellite

The source of Penzias and Wilson signal [1] and its assignment to the "CMB" may be resolvable from Earth. In the first scenario, discussed is section 3.2, the contribution to the dipole arises strictly from the "CMB" monopole, thought to be of cosmic origin. In the second scenario, the "CMB" temperature would reflect two effects: (1) the motion of the Earth through the weak microwave field also present at the position of WMAP, and (2) the additional effect from the monopole generated by the Earth. In this case, when viewed from COBE, the "CMB" temperature measured by FIRAS, and direct calibration, would not necessarily agree with that determined through visualization of the dipole.

Using the FIRAS instrument, COBE initially reports the "CMB" monopole temperature as 2.730±0.001 K [11]. This temperature should have been extremely reliable, since the FIRAS data have tremendous signal to noise [11]. Moreover, FIRAS was equipped with an external calibrator [8]. In Fixsen et al. [11] the "CMB" temperature obtained from the dipole is first reported as 2.717±0.003 K. These uncertainties are at the 1σ level. "By choosing the monopole temperature as the point to evaluate $dB\nu/dT$", the COBE team "has forced the dipole temperature to be that of the monopole" [7]. Despite this fact, the value of the "CMB" temperature, from the dipole measurement, is significantly lower than the value obtained from the monopole. The difference between these two numbers remains highly significant, even at the 99% confidence level. Considering the signal to noise using FIRAS, and the magnitude of the associated dipole, it is interesting that any systematic error exists. Such a dramatic divergence should not have been dismissed, especially since these two numbers might be expected to differ in the second scenario.

The COBE team also presents another method of assigning the "CMB" temperature, based on frequency calibration, using the CO and C^+ lines [11]. This third method yields a temperature of 2.7255±0.0009 K [11]. This value rests on factors outside the "CMB" and the dipole. While appearing to be even more precise, this value may be more prone to error and less accurate. The key determinations remain those from FIRAS, with external calibration, and from the dipole.

In Fixsen et. al [11], the COBE team recognizes that the "CMB" temperatures derived, from the monopole and from the dipole, are irreconcilable. They attribute the difference to systematic errors. In order to address this issue, the error bars on the dipole measure are arbitrarily raised to 0.007 [11]. All statistical significance is removed to account for systematic error arising from the galactic cut [11]. The inequality in these two numbers was later reexamined. In Mather et al. [12], the absolute value of the "CMB" temperature assigned using FIRAS, and the external calibrator, is shifted to 2.725± ±0.002 K (2σ; 95% confidence interval). The change is attributed to systematic errors in the calibrator [12]. Yet, in Fixsen et al. [11], the FIRAS measure was thought to be accurate to within 1 mK, based on pre-flight calibration. The new value for the "CMB" temperature, provided by FIRAS, of 2.725±0.002 K (2σ; 95% confidence interval), is now statistically different from the original value, of 2.730±0.001 K (1σ), reported by the same instrument [11, 12].

The COBE FIRAS data has excellent signal to noise. Thus, it is troubling that a significant recalibration must be completed, nearly 10 years after launch. In the end, the prudent approach is to consider that the "CMB" temperatures, obtained from the monopole (2.730±0.001 K at 1σ) and the dipole (2.717±0.003 K at 1σ), are indeed significantly different, as initially reported. It is inappropriate to make so many adjustments for "systematic errors", and thereby remove a highly significant difference between two numbers, long after completion of an experiment, especially given that COBE remains in orbit.

If the "CMB" signal truly originates for the Universe, the "CMB" temperatures evaluated, from the dipole and from FIRAS, with external calibration, must be identical. However, the values might be expected to be different in the second scenario, wherein the "CMB" arises from the Earth and a much weaker field is present in the Universe. As a result, it appears that the COBE satellite provides the first evidence that the "CMB" monopole does indeed arise from the Earth. The systematic error, first detected by COBE in the dipole evaluation of the "CMB" temperature [11], may be, in actuality, the critical proof.

The European Space Agency is now in the final stages of preparation for launching the PLANCK satellite [26]. This satellite is also equipped to scan the sky in the microwave band. Unlike WMAP, the PLANCK instruments are not differential. Consequently, this satellite should be able to finally establish that the Penzias and Wilson signal [1] does indeed arise from the Earth. Once positioned at L2, PLANCK will fail to detect the monopole signal [1]. Instead, its instrument will report only the galactic signal, the variable sources, and the weak noisy background currently attributed to anisotropy.

4 Conclusions

When Penzias and Wilson used thermodynamic principles to set a temperature of 3.5 K, they did not consider the phases of matter [1]. The signal did not change with the seasons [1], and the Earth was not at $\sim$3 K, so Dicke et. al. [5] surmised that it originated from the Universe. A powerful spectrum was present, but the concept that the receiver must be close to the source was not considered. They believed, much like Planck [20], that the laws of thermal emission [18, 27, 28] were universally applicable. Yet, Kirchhoff's law states that, for a blackbody, the temperature must be determined in the presence of thermal equilibrium, within an enclosure [2–4]. The Universe can never meet this requirement.

The oceans of the Earth cannot be treated as blackbodies, as demonstrated in Figure 1. The possibility should be considered that they are emitting at an apparent temperature, T_{app}, such that $T_{app} = T/\alpha$, where T corresponds to the real temperature and α is $\sim$100. Alpha may have a slight temperature or salinity dependence, since the Penzias and Wilson signal [1, 11] reflects a single spectrum. It is advanced that the apparent temperature, T_{app}, discussed above, corresponds to the $\sim$3 K signature previously assigned to the Cosmos. Through this simple introduction of α and T_{app}, the laws of Planck [18], Wien [27], and Stefan [28] can be reformulated for our oceans. This is the case, even if the oceans can produce additional emissions, in the infrared band, or elsewhere. The inclusion of an apparent temperature solves a problem, but the temperature is no longer real. Condensed matter physics may benefit in dissecting the lattice behavior responsible for oceanic emissions. In doing so, they may discover the importance in thinking, like Planck [18], of physical oscillators [25].

In regard to the interaction of the oceanic monopole signal, produced by the Earth, and the dipole signal, produced by motion through a weak microwave field of external origin, further insight may require the application of General Relativity [29].

It remains true that the temperature of the Universe can never be measured. That is a limitation given to us by Kirchhoff's law [2–4]. The enclosure required by Kirchhoff, during the experimental characterization of blackbody radiation, cannot be removed. At the same time, Kirchhoff's belief in universality is incorrect [3]. Indeed, this simple error will ultimately be viewed as the central oversight relative to the assignment of the Penzias and Wilson signal [1]. Kirchhoff erred 140 years ago relative to universality [3], and science failed to realize the profound implications [30]. There continues to be a lack of understanding relative to the fundamental experiments, which resulted in the laws of thermal radiation in general [18, 27, 28], and the complicating nature of liquids in particular.

Dedication

This work is dedicated to the memory of Charles-Auguste Robitaille.

First published online on November 01, 2006

References

1. Penzias A.A., Wilson R.W. A measurement of excess antenna temperature at 4080 Mc/s. *Astrophys. J.* 1965, v. 1, 419–421.
2. Kirchhoff G. Ueber das Verhaltnis zwischen dem Emissionsvermogen und dem absorptionsvermogen der Körper für Waeme und Litcht. *Annalen der Physik*, 1860, v. 109, 275–301.
3. Robitaille P.M.L. On the validity of Kirchhoff's law of thermal emission. *IEEE Trans. Plasma Sci.*, 2003, v. 31(6), 1263–1267.
4. Robitaille P.M.L. An analysis of universality in blackbody radiation. *Progr. in Phys.*, 2006, v. 2, 22–23.
5. Dicke R.H., Peebles P.J.E., Roll P.G., and Wilkinson D.T. Cosmic black-body radiation. *Astrophys. J.* 1965, v. 1, 414–419.
6. COBE web site, http://lambda.gsfc.nasa.gov/product/cobe/.
7. Fixsen D.J., Cheng E.S., Cottingham D.A., Eplee R.E., Isaacman R.B., Mather J.C., Meyer S.S., Noerdlinger P.D., Shafer R.A., Weiss R., Wright E.L., Bennett C.L., Boggess N.W., Kelsall T., Moseley S.H., Silverberg R.F., Smoot G.F., Wilkinson D.T. Cosmic Microwave Dipole spectrum measured by the COBE FIRAS Instrument. *Astroph. J.*, 1994, v. 420, 445–449.
8. Fixsen D.J., Cheng E.S., Cottingham D.A., Eplee R.E., Hewagama T., Isaacman R.B., Jensen K.A., Mather J.C., Massa D.L., Meyer S.S., Noerdlinger P.D., Read S.M., Rosen L.P., Shafer R.A., Trenholme A.R., Weiss R., Bennett C.L., Boggess N.W., Wilkinson D.T., Wright E.L. Calibration of the COBE FIRAS instrument. *Astrophys. J.*, 1994, v. 420, 457–473.
9. Bennett C.L., Kogut A., Hinshaw G., Banday A.J., Wright E.L., Gorski K.M., Wilkinson D.T., Weiss R., Smoot G.F., Meyer S.S., Mather J.C., Lubin P., Loewenstein K., Lineweaver C., Keegstra P., Kaita E., Jackson P.D., Cheng E.S.

Cosmic temperature fluctuations from two years of COBE differential microwave radiometers observations. *Astrophys. J.*, 1994, v. 436, 423–442.

10. Kogut A., Smoot G.F., Bennett C.L., Wright E.L., Aymon J., de Amici G., Hinshaw G., Jackson P.D., Kaita E., Keegstra P., Lineweaver C., Loewenstein K., Rokke L., Tenorio L., Boggess N.W., Cheng E.S., Gulkis S., Hauser M.G., Janssen M.A., Kelsall T., Mather J.C., Meyer S., Moseley S.H., Murdock T.L., Shafer R.A., Silverberg R.F., Weiss R., Wilkinson D.T. COBE differential microwave radiometers — preliminary systematic error analysis. *Astrophys. J.*, 1992, v. 401, 1–18.
11. Fixsen D.L., Gheng E.S., Gales J.M., Mather J.C., Shafer R.A., Wright E.L. The Cosmic Microwave Background spectrum from the full COBE FIRAS data set. *Astrophys. J.*, 1996, v. 473, 576–587.
12. Mather J.C., Fixsen D.J., Shafer R.A., Mosier C., Wilkinson D.T. Calibrator design for the COBE Far-Infrared Absolute Spectrophotometer (FIRAS). *Astrophys. J.*, 1999, v. 512, 511–520.
13. Klypin A.A, Strukov I.A., Skulachev D.P. The Relikt missions: results and prospects for detection of the Microwave Background Anisotropy. *Mon. Not. Astr. Soc.*, 1992, v. 258, 71–81.
14. WMAP website, http://map.gsfc.nasa.gov/.
15. Bennett C.L., Halpern M., Hinshaw G., Jarosik N., Kogut A., Limon M., Meyer S.S., Page L., Spergel D.N., Tucker G.S., Wollack E., Wright E.L., Barnes C., Greason M.R., Hill R.S., Komatsu E, Nolta M.R., Odegard N., Peiris H.V., Verde L, Weiland J.L. First-year Wilkinson Microwave Anisotropy Probe (WMAP) observations: preliminary maps and basic results. *Astrophys. J. Suppl.*, 2003, v. 148(1), 1–27.
16. Hinshaw G., Nolta M.R., Bennett C.L., Bean R., Dore O., Greason M.R., Halpern M., Hill R.S., Jarosik N., Kogut A., Komatsu E., Limon M., Odegard N., Meyer S.S., Page L., Peiris H.V., Spergel D.N., Tucker G.S., Verde L., Weiland J.L., Wollack E., Wright E.L. Three-year Wilkinson Microwave Anisotropy Probe (WMAP) observations: temperature analysis. *Astrophys. J.*, 2006, *submitted*.
17. Berger A. An introduction to the International Symposium George Lemaître. In: *The Big Bang and George Lemaître*, D. Reidel Publishing Company, Dordrecht, 1984, p. vii–xiv.
18. Planck M. Ueber das Gesetz der energieverteilung in Normalspectrum. *Annalen der Physik*, 1901, v. 4, 553–563.
19. Robitaille P.M.L. WMAP: a radiological analysis. *Progr. in Phys.*, 2007, v. 1, 3–18.
20. Planck M. The theory of heat radiation. Philadelphia, PA., P. Blakiston's Son, 1914.
21. Ulaby F.T., Moore R.K., Fung A.K. Microwave remote sensing active and passive — Volume 2: Radar remote sensing and surface scattering and emission theory. London, Addison–Wesley Publishing Company, 1982, p. 880–884.
22. Robitaille P.M.L. NMR and the Age of the Universe. *American Physical Society Centenial Meeting*, BC19.14, March 21, 1999.
23. Robitaille P.M.L. The MAP satellite: a powerful lesson in thermal physics. *Spring Meeting of the American Physical Society Northwest Section*, F4.004, May 26, 2001.
24. Robitaille P.M.L. The collapse of the Big Bang and the gaseous Sun. *New York Times*, March 17, 2002.
25. Robitaille P.M.L. WMAP: an alternative explanation for the dipole. *Fall Meeting of the American Physical Society Ohio Section*, E2.0001, 2006.
26. PLANCK website, http://www.rssd.esa.int/index.php?project=PLANCK&page=index.
27. Wien W. Ueber die Energieverteilung in Emissionspektrum eines schwarzen Körpers. *Ann. Phys.*, 1896, v. 58, 662–669.
28. Stefan J. Ueber die Beziehung zwischen der Wärmestrahlung und der Temperature. *Sitzungsberichte der mathematischnaturwissenschaftlichen Classe der kaiserlichen Akademie der Wissenschaften*, Wien 1879, v. 79, 391–428.
29. Rabounski D. The relativistic effect of the deviation between the CMB temperatures obtained by the COBE satellite *Progr. in Phys.*, 2007, v. 1, 24–26.
30. Robitaille P.M.L. The Solar photosphere: evidence for condensed matter. *Prog. in Phys.*, 2006, v. 2, 17–21.