The Planck Satellite LFI and the Microwave Background: Importance of the 4 K Reference Targets

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Armed with ~4 K reference targets, the Planck satellite low frequency instrument (LFI) is intended to map the microwave anisotropies of the sky from the second Lagrange point, L2. Recently, the complete design and pre-flight testing of these ~4 K targets has been published (Valenziano L. et al., JINST 4, 2009, T12006). The receiver chain of the LFI is based on a pseudo-correlation architecture. Consequently, the presence of a ~3 K microwave background signal at L2 can be established, if the ~4 K reference targets function as intended. Conversely, demonstration that the targets are unable to provide the desired emission implies that the ~3 K signal cannot exist, at this location. Careful study reveals that only the second scenario can be valid. This analysis thereby provides firm evidence that the monopole of the microwave background, as initially detected by Penzias and Wilson, is being produced by the Earth itself.

1 Introduction

Over the years, I have expressed growing concern [1] about the origin of the microwave background [2]. My evaluation has focused on three fronts. First, I have highlighted that errors exist in the derivation of Kirchhoff's law of thermal emission (e.g. [3, 4] and references therein) which renders its use inappropriate in physics. The universality of blackbody radiation is invalid on both theoretical and experimental grounds [3, 4], making it impossible to assign an absolute temperature to the Penzias and Wilson [2] signal. At the same time, I have emphasized that the law of equivalence between emission and absorption, under conditions of thermal equilibrium, remains valid [4]. This is properly referred to as Stewart's law [5]. Second, I have questioned the assignment of the microwave background to the cosmos [6], invoking (see [1] and references therein), along with Borissova and Rabounski [7], that the Earth's oceans are responsible for this signal. It is the presence of the hydrogen bond within water which gives cause for reconsideration [8]. The emission of this bond has not yet been assigned for the Earth's spectrum, despite the reality that our planet is 70% water. Finally, I have outlined shortcomings in the measurements of the microwave background, especially relative to the COBE [9] and WMAP [10] satellites. Concern, relative to the results of these satellites, has also been voiced by a number of other groups [11–18]. Now, the Planck mission [19] is drawing the attention of the scientific community. But early reports [20] and system evaluations [21] should provoke uneasiness. This can only be appreciated when the function of the low frequency instrument (LFI) is understood [22–26]. It is through the analysis of the LFI's performance that the origin of the microwave background can be established [27].

On July 30, 2009 the ESA Planck team wrote: "*In the case of LFI, the results show even better than expected performances due to benign space environment and an improved tuning process*" [20]. On first consideration, it would seem that the monopole of the microwave background was present at L2, as expected by the astrophysics community. Unfortunately, upon careful review, this statement directly implies that the opposite situation has taken place. There can be no 3 K signal at this location. The arguments center on the functioning of the ~4 K targets, whose full description only recently became available [21]. When the performance of these references is considered, in combination with the function of the pseudo-correlation receivers [22–26], solid evidence emerges that there can be no ~3 K signal permeating space.

2 The performance of the Planck LFI

The proper characterization of the ~4 K reference loads [21] and LFI [22–26] on the Planck satellite is critical to understanding whether the monopole of the 2.7 K microwave background is present at L2 [27]. This situation occurs, since the presence of a monopole cannot be ascertained with the high frequency instrument, HFI [28]. Relative to the HFI, the Planck team writes: "*Plank cannot measure accurately the monopole (uniform part of the emission) because many sources contribute (telescope, horns, filters,…)*" [29]. Thus, the HFI bolometers, though operating in absolute mode, can receive thermal photons from the spacecraft itself much of which is in a 50 K environment. As Planck's mirrors are exposed to 300 K at L2, photons of instrumental origin can enter the bolometers, making it difficult for the HFI to extract the ~3 K background signal from instrumental foregrounds. It is anticipated that such effects are less important at the frequencies of the LFI. Consequently, it seems that only the LFI [22–26] can properly address the existence of a monopole at L2. The issue is critical since, in the absence of the monopole, any anisotropy measurements by this satellite would have little or no scientific value.

Expected performance of the PLANCK LFI receivers		
	Sky Temperature ~3 K	Sky Temperature ~0 K
Reference ~4 K	As expected	Poor
Reference ~0 K	Poor	Better than expected

Table 1: Summary of the scenarios which impact the expected performance of the pseudo-correlation receivers on the Planck satellite. Four possibilities exist depending on the actual brightness temperatures of the sky and the reference targets. It is assumed that the sky can be either at ~3 K (the Penzias and Wilson temperature [2]) or at ~0 K [1]. Similarly, the reference targets can be either operating as intended near 4 K [21], or are unable to generate a meaningful blackbody spectrum, ~0 K (as proposed herein).

As discussed in considerable detail [22–26], the low frequency instrument (LFI) functions as a pseudo-correlation receiver, wherein the sky signal is constantly being compared against a ~4 K reference signal. In this configuration, the receiver displays optimal performance only when the two input signals display approximately the same amplitude. Under these conditions, the input offsets are nearly identically zero, the knee frequency of the receiver is minimized and so is the $1/f$ noise [22–27]. The LFI team states, "*to minimize the 1/f noise of the radiometers, the reference blackbody temperature should be as close as possible to the sky temperatures (~3K)*" [21]. This represents an ideal situation, wherein the mechanical configurations of both receiver chains are identical. In practice, this cannot be achieved, as the reference horns are much smaller than the sky horns. Thus, a gain modulation factor is utilized to partially account for such effects [21–27]. In any case, the radiometric temperature difference between the signals captured by the sky and the reference horns constitutes a critical element in receiver performance. In order for the LFI to function properly, the sky signal must balance the reference signal.

There are four scenarios which need to be considered relative to the performance of the LFI receiver chains. These scenarios are summarized in Table 1 and are described as follows:

2.1 Sky at ~3 K, reference loads at ~4 K

The cosmology community is expecting a 2.7 K monopole signal at L2 [2]. In addition, some thermal photons might be expected from the galactic foreground and the spacecraft itself. As a result, the receiver would have optimal performance, if the sky signal was being compared with a reference signal at 2.7 K. However, the LFI group mentions that "*there is no convenient spacecraft source of 2.7 K with sufficient cooling power*" [21], and chose to passively cool the reference loads to ~4 K by mounting them on the 4 K thermal shield of the HFI. At first glance, this appears to be an elegant solution. But in actuality, as will be seen in section 3, this placement demonstrates suboptimal conditions relative to the principles of heat transfer. In any event, should the sky be at 2.7 K and the ~4 K load properly constructed, the receiver performance would be as expected from pre-flight modeling. Being approximately balanced, the sky and reference signals would generate a receiver performance matching the pre-flight technical specifications [22–26].

2.2 Sky at ~0 K, reference loads at ~4 K

Alternatively, if the monopole signal does not exist at L2 and *if the reference loads are truly acting as ~4 K blackbody sources*, a tremendous input offset would be generated in the receiver. The knee frequencies would rise, as would the $1/f$ noise. The result would be significant stripes in the maps generated by the satellite. These concerns were previously outlined in detail [27], *on the assumption that the ~4 K reference loads would be properly designed and able to provide the needed emission.*

2.3 Sky at ~3 K, reference loads acting as ~0 K sources

An interesting case can also manifest itself if the microwave sky is indeed at 2.7 K, but the reference loads, due to improper fabrication, do not produce an emission corresponding to a ~4 K blackbody source. In the extreme, the reference loads might be considered as producing no valuable emission signal. This would produce an emission from the loads indistinguishable from a ~0 K source, despite their ~4 K actual temperature. Under such a scenario, a tremendous imbalance would once again be produced in the receivers, the knee frequencies would rise, and $1/f$ noise would be manifested in the resultant maps.

2.4 Sky at ~0 K, reference loads acting as ~0 K sources

Finally, there is the possibility that the microwave sky is at ~0 K and that improperly manufactured reference loads produce a signal much inferior to the expected ~4 K source. Once again, in the extreme, the reference loads might be considered as producing no valuable emission signal, thereby behaving as ~0 K sources. Interestingly, in the case, the performance of the spacecraft would be better than expected. Only relatively small microwave emissions from the sky would be observed, and their lack of power would be complemented by the lack of power coming from the reference loads.

Of these four scenarios, only the first and last can be valid, given what we now know [20] about the performance of the LFI [22–26]. In fact, assuming that the ~4 K references were properly constructed, the performance of the LFI receivers, by themselves, would prove that there is indeed a monopole signal at L2 [27]. Everything hinges on the quality of the ~4 K reference blackbodies [21]. But given that "*even better than expected performances*" [20] were obtained, there is concern that the ~4 K reference loads are not functioning as they should and that the last scenario (Sky at ~0 K, reference loads ~0 K) is the one which will prevail. Unfortunately, a detailed description of the ~4 K loads was not available to the general public until December 29, 2009 [21]. The materials contained in this work provide enough information to resolve the question.

3 The ~4 K Reference Loads on the PLANCK LFI

A schematic representation of a ~4 K reference load system for the LFI is displayed in Figure 1. Each reference load system is comprised of a small horn, separated from a target by a 1.5 mm gap in order to preserve thermal isolation between the 20 K shield which houses the LFI and the ~4 K shield housing the HFI [21]. The Planck team states: "*One of the main requirements of the 4KRL design was to minimize the heat load on the HFI to a value lower than 1 mW. Safety considerations (a thermal short between the two instruments will prevent the HFI to work) lead to mechanically decouple the loads, mounted on the HFI external shield, from the LFI radiometers, at 20 K*" [21]. They continue: "*This solution implies the presence of a gap in the radiometer reference arm, through which external spurious signals can leak in the radiometers*" [21]. They attempt to address this issue, by introducing grooves on the edge of the horn, in order to limit spillover. In addition, they state: "*Targets also need to be small and placed in the very near field of the reference horns to reduce the leak from the gap*" [21]. The LFI group notes that: "*the conceptual design is therefore based on small absorbing targets, mounted inside a metal enclosure ("case") to confine the radiation...*" [21].

The satellite team relays that: "*Each target is basically a rectangular Eccosorb$^{\text{TM}}$ CR block, shaped for optimal matching with the incoming field. The back part is made of highly absorbing CR117, while the front sector, made from CR 110, reduces the mismatch*" [21]. The absorbing material for each target is then enclosed on 5 sides, within an aluminum casing. These targets are mounted on the 4 K shield of the HFI using "*stainless steel (AISI304) thermal washers*" which are "*interposed between the loads and the interface points to the HFI*" [21]. The LFI group explains that: "*These are small cylinders (typically 5 mm long, 1 mm wall thickness) whose dimensions are optimized to dump temperature fluctuations in order to meet requirements*" [21]. Apparently, the ~4 K reference loads are then attached directly through the washers onto the HFI 4 K shield with "*screws (mounted on the HFI)*" [21].

The designers opt to conduct heat out of the ~4 K reference loads into the 4 K shield of the HFI in order to achieve a stable temperature. They enclose the Eccosorb material in an aluminum casing to help ensure that conductive paths are open which can suppress any thermal fluctuations within the loads. In so doing, they have introduced Type-8 errors into their system [30]. In fact, the LFI group, during the testing stage, observes that they must work to better suppress thermal fluctuations. Therefore, they attempt to increase thermal fluctuation damping. They write: "*the RF and thermal test results were used to further refine the design (i.e. thermal dumping was increased, mounting structure was slightly modified to facilitate integration)*" [21] and "*The optimization of the thermal washers allowed to increase the damping factor...* " [21]. Thus, they are trying to adopt a delicate balance between the necessity to cool the references on the 4 K shield and the need to efficiently address heat fluctuations: "*Cases, supported by an Al structure, are mounted on the HFI using Stainless Steel thermal decouplers (washers), which allows to carefully control the thermal behavior*" [21]. In reality, while the presence of the washers and their construction primarily impacts the time constants for damping heat fluctuations, they still provide a very efficient conductive heat path out of the targets. After all, the references remain cooled by conductive mechanisms which rely on thermal contact with the 4 K HFI shield. Herein is found the central design flaw of the Planck LFI.

3.1 Conductive paths and Type-8 errors

The Planck reference loads are cooled by conduction, not self-radiation. As a consequence, there is no reason to expect that the reference loads can output any photons at ~4 K. Being cooled by conduction, the references do not need to invoke thermal radiation in achieving steady state. Indeed, the Planck team writes: "*Thermal interface is dominated by conduction through thermal washers*" [21]. They continue: "*Metal parts are assembled using Stainless Steel screws at high torque, to make thermal contact as close as possible to an ideal value*" [21]. Relative to thermal modeling they write: "*the 70 GHz loads are assumed to be perfect thermal conductors, due to their small thickness and mass*" [21]. Hence, the LFI group members, by introducing conduction directly into their loads, have rendered them ineffective as ~4 K blackbody sources.

Certainly, in order for an object to act as a true blackbody, it must be devoid of all outgoing conductive paths of heat transfer. Reference targets must be spatially isolated from their surroundings, such that only radiation can dominate [30]. Yet, the ~4 K targets on the Planck satellite are configured such that net conduction of heat out of the target is allowed to take place. The targets are mounted onto the 4 K shield of the HFI, and heat can flow continuously using conduction into that heat sink. Since the targets are continually exposed to a 20 K environment, their temperature is being ensured by conduction, not heat radiation. In this manner, thermodynamic steady state and a stable temperature is maintained, but through conduction, not heat radia-

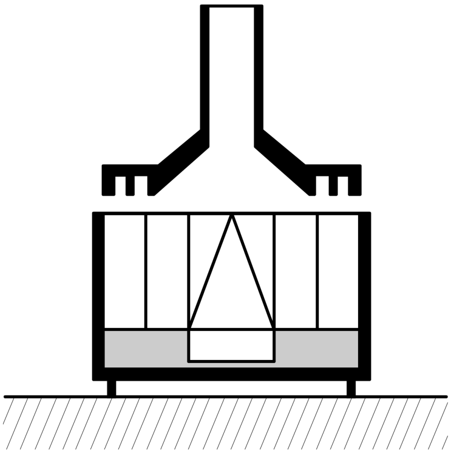

Fig. 1: Schematic representation of a Planck LFI reference load. Each load is comprised of a horn (upper section) and a target (middle section) separated by a 1.5 mm gap. The targets are constructed from molded Eccosorb (CR-110 or 117) absorber surrounded by an aluminum casing which acts to preserve thermodynamic steady state within each unit, using conduction. Heat is allowed to flow out of the target casing through a conductive path into the 4 K shield of the HFI (represented by the cross hatched area in the lower section). This path is provided by stainless steel cylindrical washers (see text and [21] for more detail). By providing a conductive path out of the target, the Planck LFI team has created a situation wherein a Type-8 error is introduced [30]. By itself, such a design ensures that these targets cannot operate as ~4 K loads as intended (see text).

tion. The Planck LFI ~4 K targets are directly linked, which good thermal contact, through stainless steel washers, onto a 4 K shield. Such a scenario will not only reduce the brightness temperature, relative to the real temperature, it is likely to completely inhibit the emission of photons [30]. In this respect, the presence of conductive paths in the Planck LFI ~4 K targets provides a much worse scenario for achieving the expected brightness temperature, then when water permeates soil [30].

Rather than using conductive washers, stainless steel screws, and an aluminum casing, it would have been preferable to encase the Eccosorb in a strong insulator suspended in air with thin non-conducting support rods. Such a load could then be enclosed in a perfectly reflective shield at 4 K. It is only through this kind of geometry that a ~4 K load can suitably act as a reference.

By itself, the Type-8 error indicates that no 3K signal exists at L2. The loads do not need to cool by radiation. Accordingly, they do not need to emit a single photon. They are unable to act as blackbodies in the intended capacity. Still, beyond the Type-8 error, there are sufficient concerns with the ~4 K reference loads, that their lack of functionality can be established. In order to properly follow these issues, it is important to consider all of the potential errors related to measuring emissivity using return-loss methods on microwave targets [30].

3.2 Type-3, -4, -5, -6, and -7 errors

First, the ~4 K reference loads are subject to a Type-3 error [30]. Radiation from the horn during testing can be diffracted on the edge of the target casing through the 1.5 mm thermal gap into the surroundings. This is because, unlike the horns, the casing contains no edge structure which can minimize diffraction. Secondly, the ~4 K reference systems are subject to a Type-4 error, wherein incident radiation from the horn, experiences diffuse reflection on the surface of the Eccosorb, and is lost through the gap into space [30]. Similarly, Type-5 errors can occur. Incident radiation, in this case, enters the Eccosorb, is reflected on the casing, and then, after reentry into the absorber, becomes scattered into space through the gap. In the same way, a Type-6 error can occur [30]. That is, incident radiation which traverses the Eccosorb layer can be reflected by the casing, and on re-entry into the absorber, is diffracted upon striking the edge of the casing. Once more, such radiation could exit the system through the 1.5 mm thermal gap which separates the horn and the target (see Figure 1). In addition, Type-7 errors exist as previously discussed in detail [30]. These are errors which depend on the geometry of the target. They occur when a transmissive absorber is mounted on a reflective metallic casing and their characteristics have been addressed [30].

3.2.1 Planck test data, calculations, and Type-10 errors

There is also the possibility of a Type-10 error [30]. Namely, because the Planck team chose to use so little material in their casings, they have enclosed only weak absorbers. In so doing, they introduce the likelihood of generating standing waves within the casings during testing. This would represent a Type-10 error [30].

A careful study of Planck LFI return-loss traces provides strong evidence that such standing waves do exist. For instance, the Planck team presents Figure 26 [21], wherein the return-loss is measured. A single such tracing, obtained from a 30 GHz horn-target assembly, is extracted from this Figure to generate Figure 2 herein. Note that the network analyzer tracing has pronounced resonances extending as low as −50 dB at some frequencies. These resonances should not be present if the target is black [3]. In fact, the presence of such resonances, by itself, provides ample evidence that the 30 GHz targets are far from being black.

As a result, it is clear that the return-loss measurements published by the Planck team [21] far overstate the actual performance of the reference targets, if these values are directly utilized to calculate emissivity. In fact, this is evident by examining data provided by the Planck team. Consider, for instance, Figure 10 in [21] which is reproduced herein as Figure 3. This represents a computational analysis of field distributions that takes place both inside and around the targets, during testing with microwave radiation. It is evident, from this figure, that the targets are unable to localize microwave

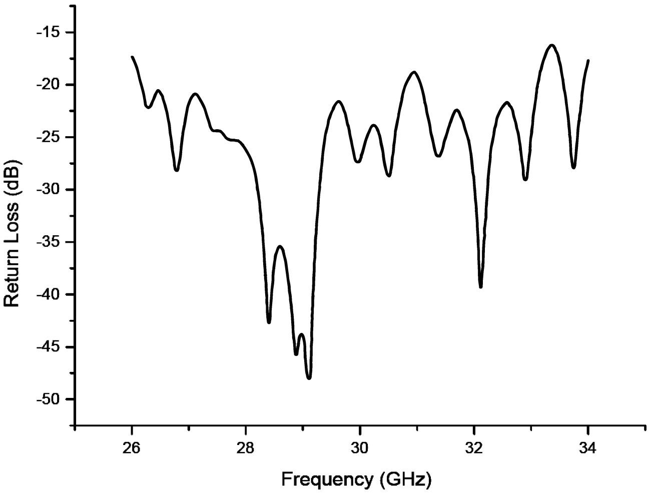

Fig. 2: Schematic representation of a network analyzer tracing for a 30 GHz reference target system, as provided by the Planck LFI team [21]. This particular tracing was extracted from Figure 26 in [21] in order to better visualize its features. Note the presence of significant resonances on this tracing, indicating the existence of standing waves within the horn-target system. It is well known, based on elementary considerations in electromagnetics [3], that cavities, waveguides, and enclosures, at microwave frequencies, can sustain standing waves in a manner depending on their size and geometry (see [3] and references therein). This problem is particularly important when the dimensions of the target approach the wavelengths of interest. In this case, 30 GHz corresponds to a wavelength of ~1 cm in vacuum. The target casings are 3.3 × 3.3 × (~ 2) cm (see Table 1 and Figure 12 in [21]). The presence of such resonances in the ~4 K reference loads, demonstrates unambiguously that the targets are not black. In fact, the targets are still acting as resonant devices [3]. For a blackbody to exist, all such resonances must be suppressed (i.e. as ideally seen by a constant −50 dB tracing across the spectral range). In this case however, and when combined with the data in Figure 3, it appears that approximately −15 to −20 dB of return loss can be accounted for by leakage from the 1.5 mm gap. Then, between −20 to −25 dB of return loss can be attributed, at certain frequencies, to the existence of resonance features. Note that 29 GHz gives a wavelength of ~1.03 cm in vacuum, and perhaps a little more in Eccosorb (see [30] and references therein). As such, the resonances at 28.5–29.2 GHz correspond almost exactly to 3 wavelengths in a square 3.3 cm enclosure. Reproduced from [21] with permission of the IOP and L.Valenziano on behalf of the authors and the Planck LFI consortium.

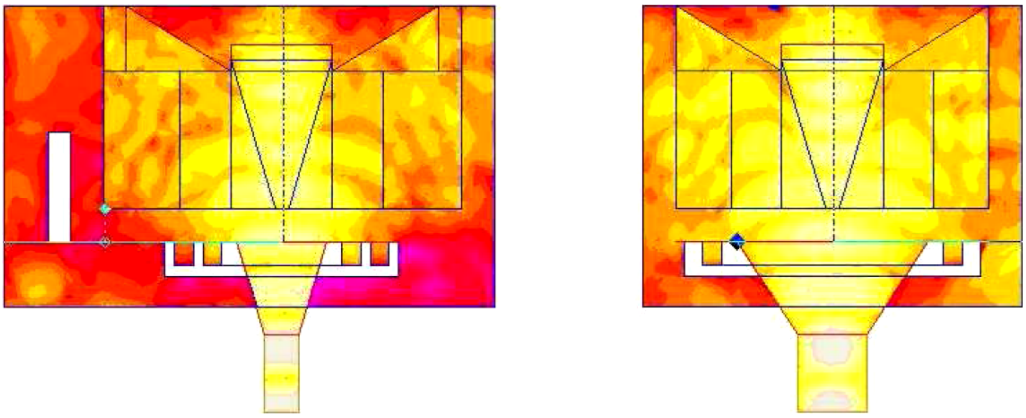

Fig. 3: Computational determination of the E-field distribution at 70 GHz for a horn-target assembly as reproduced from Figure 10 in [21]. White areas represent perfect conductors, whereas regions of increased brightness depict more intense fields [21]. The left panel corresponds to PHI = 90 while the right panel to PHI = 0. Further details are available in [21]. Note how the target is unable to localize microwave energy. Leakage of radiation beyond the 1.5 mm gap separating the horn and the target is evident, especially in the right panel. If leakage appears to be less intense in the left panel (examine the left edge of the casing), it is because the horn dimension in this cut is substantially smaller than the target. Nonetheless, some restriction of radiation is visible on the left edge of the casing in the left panel. This acts to confirm that none of the other edges are able to confine the radiation. Note also that the section of CR-117 absorber below the pyramid is actually acting to reflect rather than absorb the radiation. This is especially evident in the left panel (note red area beneath the central pyramid (see [21] for more detail). From these calculations, it is apparent that the Planck LFI targets at 70 GHz are not black, enabling dissipation of energy well beyond the horn-target assembly. Unfortunately, the Planck team does not display corresponding results at 30 and 44 GHz. Reproduced from [21] with permission of the IOP and L.Valenziano on behalf of the authors and the Planck LFI consortium.

energy within the casing. In fact, especially in the PHI = 0 cut (see Figure 3, right side), microwave power is flowing freely throughout the space in front and around the target. No localization of energy is evident. This provides solid evidence that the return-loss measurements far overstate the performance of these devices when attempting to evaluate emissivity.

4 Discussion

Consequently, the Planck LFI group has not properly measured the emission of their reference loads. "*Indeed, Valenziano et al. [21] do not even provide the estimated emissivity of their targets. By itself, this constitutes an implicit indication that these values cannot be properly determined, with such methods, as I previously stated*" [9].

Faced with Type-3, -4, -5, -6, -7 and -10 errors, the target is unable to absorb the microwave energy from the horn and the latter is able to leak out of the gap into the surrounding space. This occurs even though the horn has edge structure to prevent leakage into the gap as such a configuration neglects the chaotic propagation of microwave energy which can occur within the target. Nonetheless, the Planck team assumes that, in making their return-loss measurements, no leakage into the gap takes place, even though such phenomena is evident in their own calculations (see Figure 3). They further assume that their casing cannot support any standing waves (see Figure 2).

As such, relative to the Planck satellite LFI, the published return-loss values, do not properly represent the emissive power of their reference targets. The latter is much less than expected, both due to gap leaks, as mentioned above, and because return-loss methods overestimate the true emission in the presence of metal casings (Type-7 errors). The presence of the aluminum casings provides ample opportunities to set up standing waves in front of the horn (Type-10 errors). Such waves are present in the traces displayed by the Planck team (see Figure 2 herein and Figure 26 in [21]). This further illustrates that these reference blackbodies are not black. Ultimately, the most serious concern is the presence of a Type-8 error [30]. Conduction has been allowed as the key means of establishing thermodynamic steady state. Subsequently, it can be said that reference blackbodies do not even exist on the Planck satellite.

Given this information, the members of the scientific community, independent of the Planck team, can now either confirm or refute the existence of a monopole at L2. They may do so by concurring with this analysis and establishing the emissivity of the ~4 K reference loads on the LFI. If the loads truly act as ~4 K references, then the monopole signal must be present at L2. Conversely, as suggested by this work, if the ~4 K references are unable to emit properly as ~4 K blackbodies, then the excellent performance of the LFI implies that there is no monopole at L2 and that this signal does indeed arise from the Earth itself [1].

Unfortunately, it is rather difficult to establish the extent to which a reference target is black in the microwave. However, the following approaches might be considered. At the onset, the measurements must not occur inside an anechoic chamber. Such chambers suppress leaked signals and thereby overstate the emissivity of the target obtained with return-loss measurements. Therefore, such a setting should be avoided. Relative to a small target, like those on the Planck satellite [21], it might be possible to ascertain that they are very poor emitters in the following way. First, a duplicate horn must be placed inside a perfectly reflecting enclosure. The return-loss perfomance in such a case will be poor. This is because virtually all the energy emitted by the horn becomes trapped by the enclosure. This energy would then be able to return to the network analyzer, provided that it is not involved in the formation of standing waves either in the enclosure or within the horn [3].

Once this has been accomplished, the experiment must be repeated, but this time, the target must be placed in front of the horn with a 1.5 mm spacing, as noted by the Planck team. The entire assembly must be once again positioned inside a perfectly reflecting enclosure, wherein the horn and target geometry are preserved. A single drive mechanism must enter the enclosure. As for the target, two cases should be considered: one where a conductive path to the enclosure exists and one where it is suppressed. Once again, the network analyzer would be connected. But this time, any power incident on the target which is not absorbed will be reflected by the walls. Indeed, standing waves will be set up inside either the aluminum casing itself, or the enclosure [3], both of which are acting now as microwave cavities. These standing waves will create oscillations on the network analyzer tracing. By constructing a box whose dimensions can be gradually modified, it should be possible to alter the pattern of standing waves in the cavity. A target will be considered black only when all modifications of the enclosure dimensions, or that of the casings, can yield no changes on the return-loss signal proving that no standing waves exist. Ideally, in this case, the return-loss tracing will display a constant value across the spectral range with no trace of resonance. This can solely occur if all radiation, incident on the target, is absorbed. In this fashion, the blackness of a radiator can be established. Interestingly, this test, so critical to the proper scientific evaluation of the Planck mission, is readily accessible, and at low cost, by most of the electromagnetic laboratories of the world.

However, given our current knowledge of the LFI reference loads [21–27], it is already evident that the Planck targets within this test setting will display strong resonances. Indeed, from the analysis provided above, the references cannot be operating as blackbodies relative to the frequencies of interest. The Planck team has permitted conduction in their system. As a result, the reference targets are envisioned to have constant uniformity of temperature. In fact, this is assured by dumping heat through conduction into the 4 K shield at all times during flight, in violation of Planck's requirement that conduction not transpire. Max Planck writes: "*For the heat of the body depends only on heat radiation, since, on account of the uniformity in temperature, no conduction of heat takes place*" [31]. To complicate matters, the Planck team ignores the reality that good conductors make poor emitters (see [3] and references therein). This fact has been known for more than 100 years. Yet, the LFI consortium unknowingly has created a situation where they believe that their reference loads can be treated as perfect conductors. They write that: "*the 70 GHz loads are assumed to be perfect thermal conductors, due to their small thickness and mass*" [21]. They have created these "perfect conductors" by enclosing a small amount of absorber within a metallic enclosure. This issue is discussed in greater detail in [30], but nonetheless, the design of the Planck LFI reference targets reflects a sidestep of elementary thermodynamic principles.

In closing, for nearly 50 years, the microwave signal first detected by Penzias and Wilson [2], has fascinated scientists. Yet, all too quickly, its cosmological nature was embraced [6]. In fact, the publication of the interpretation [6] preceded the discovery itself [2]. Now, with the aid of the Planck satellite, the electromagnetics laboratories of the world should be able to confirm or refute the existence of a ~3 K cosmic signal. The key to this puzzle rests in the understanding of the LFI and reference targets [21–27]. Soon, scientists should reach the definitive answer. In the end, in this age of concern for the global climate, mankind cannot long afford to maintain that a signal of Earthly origin [1] is, in fact, cosmic [6]. Enough evidence is already beginning to build [1, 3, 4, 7–18] indicating that physics, astrophysics, and geophysics stand on the verge of a significant reformulation. In any event, the definitive proof that the monopole of microwave background belongs to the Earth has now been provided.

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Dedication

This work is dedicated to Thomas Kerner Helgeson.

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