

New Thermodynamics: Inelastic Collisions, Blackbody Radiation, Entropy and Light

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ABSTRACT

Most collisions that we witness are inelastic. Irrationally, the sciences have evolved around elastic collisions, which allows for simpler mathematical modelling. Since a result of inelastic collisions are photons, we examine the feasibility of an ensemble of inelastic collisions producing a blackbody spectrum. This will lead to reconsideration of how the light that governs our lives is produced, i.e., light from both the stars and incandescent lightbulbs.

A brief discussion of entropy being a mathematical contrivance based upon elastic collisions is included. A consequence of collisions being inelastic becomes, entropy can only be an approximation when applied to the real world. And this fits well with “New Thermodynamics”.

Keywords: blackbody radiation, entropy, inelastic collisions, lightbulb, Sun.

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I. INTRODUCTION

The physics community treats collisions on both the atomic and cosmological scales as elastic, even though we accept that the majority of collisions in daily life are clearly inelastic, e.g., two cars colliding.

By providing a revised kinetic theory that is a superior fit to known empirical findings, this author has challenged the acceptance of elastic intermolecular collisions [1]-[3]. Basically, one must transpose the accepted analysis. Instead of starting with a gas molecule's momentum and kinetic energy and then claiming that both are conserved in an elastic collision with a system's walls, one must accept that the relatively massive walls impose their kinematics onto the gas molecule, allowing for gas molecules to still have energies that are multiples of $kT/2$ but in inelastic collisions. Importantly, it challenges both equipartition and degree of freedom-based arguments.

The basis for the illusion of elastic collisions has been discussed by this author [3], [4]. The incorrect application of elastic collisions has enabled the further application of entropy to cosmology, i.e. as the arrow of time [5]-[7], along with other interpretations of entropy being applied, such as the application of Shannon's information theory [8].

This author argues that entropy is nothing more than mathematical contrivance [3], [9]. Furthermore, this author has clearly redescribed thermodynamics in simpler terms that expunge entropy [3], [10]-[13]. Others have also questioned entropy's application in thermodynamics [14], [15].

Importantly, one cannot challenge entropy without also challenging the second law, as this author has done [3], [12], [16], in a manner quite different than the challenges from

others [17]. The second law arguably originates with the idea that perpetual motion cannot exist, which can be summed by Lord Kelvins statement: “*It is impossible to transform an amount of heat completely into work in a cyclic process in the absence of other effects*” [3], [18].

Accepting that, at all scales, the vast majority of collisions are inelastic challenges the fundamental constricts behind accepted statistical thermodynamics. Understandably, the assumption of elastic collisions simplifies the math associated with an ensemble of colliding particles in incessant motion. Seemingly, it was justified by experiments, however this author has discussed that such experimentation renders the illusions of elastic collisions [4] and accordingly can only provide an approximation (often rough) when applied to real world situations.

Moreover, it is now known that even collisions at the electron scale are now considered to be inelastic [19], so why do we so strictly adhere to this assumption, which at best can only give an approximation. This assumption can further complicate the sciences.

By not entering the various quagmires associated with entropy, statistical mechanics, and quantum mechanics, the theories in cosmology would simplify once suitable interpretations are determined. Rather than take on the enormity of such scientific realm's hidden faults, this author will take a humbler route, i.e., again clearly showing that other simpler logic-based interpretations do exist. The following reconsideration of blackbody radiation from stars, based upon inelastic collisions, then becomes a continuation of this author's new thermodynamics [3].

Accepting these simpler interpretations will render thermodynamics into a science based on fundamental

sequential logic rather than mathematical conjecture [3]. The implication is that the accepted mathematical foundations are based upon ensembles of elastic collisions, i.e., edification concerning entropy and its real-life relevance will be needed.

Whether theoretical, or experimental, more than one analysis can be used to explain any given result. Accepting this, renders mathematics into a language, with most of what we witness being explainable in a variety of languages. Providing the simplest theoretical explanation for what we witness subscribes to Occam's razor. It will be left to others to elaborate upon the more complex mathematical intricacies concerning what is described herein.

II. RADIATION FROM INELASTIC COLLISIONS

If the majority of molecular (inter and/or intra) collisions are inelastic, where are the resulting photons from such collisions? Certainly, on Earth's surface such photons would easily be lost in the dynamics of the surrounding witnessed wizardry.

What is needed is a protected location, where the majority of externally sourced photons are blocked from one's analysis. Consideration has led this author to speculate that an ideal location to witness these collision's result is a cavity surrounded by condensed matter that is thick enough to block out external photons, as illustrated in Fig 1. [3], [20].

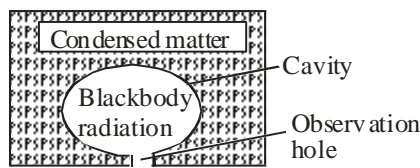


Fig. 1. Blackbody radiation in a cavity with an observation hole.

This has been extensively studied in the 19th century and was coined blackbody radiation, which obeys the Stefan-Boltzmann law.

The Stefan-Boltzmann law states that the total emitted power [(energy emitted)/time] is proportional to the matter's temperature to the fourth power [3], [21]:

$$Power = A\epsilon\sigma T^4 \tag{1}$$

where ϵ =emissivity. Note that: $\epsilon=1$ for blackbody, while $\epsilon < 1$ for graybody.

$$\sigma = 2\pi^5 k^4 / 15h^3 c^2 = 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4 \text{ (J/sm}^2\text{K}^4\text{)}.$$

A = surface area.

In a nutshell, it is accepted that oscillating charges can produce EM waves. Extrapolating, the 19th through 20th century traditional belief was that blackbody radiation is produced in cavities surrounded by condensed crystalline matter. Issues such as the UV catastrophe, were resolved by a combination of Einstein's particle nature of photons, and Planck's mathematical analysis limiting the cavities surrounding condensed matter to being crystalline [21].

Once more, two different theories now explain a given experimental result. Is the traditionally accepted interpretation correct, or is this author's consideration

correct? Perhaps blackbody radiation emanating from a hole in a cavity, is some combination of both.

When contemplating stars, of interest is the need for the condensed matter to be both crystalline and a cavity, i.e., enclosure. Accepting Planck's mathematical interpretation along with our Sun being gaseous (hydrogen and helium) does beg the question: "How can our Sun emit blackbody radiation?" This may have influenced Robitaille in his considerations that our Sun is not gaseous [22], [23].

For clarity, a review of our basic interpretation of our Sun is now given.

III. OUR SUN

Our Sun is currently theorized to have a central core followed by a radiative zone, and a convection zone, along with an outer atmosphere consisting of the photosphere, chromosphere and corona, as illustrated in Fig. 2. In the current model photons are produced in the core, and it takes millions of years for their energy to pass through both the radiative and convective zones, into our Sun's atmosphere.

Although our Sun does not reside within an enclosure, the notion of the time it takes for the photons to exit our Sun's atmosphere has alleviated such concerns. The dispute as to whether the Sun has a hard surface extends into the 20th century, with observational astronomers losing out to the likes of Eddington and others [24], [25].

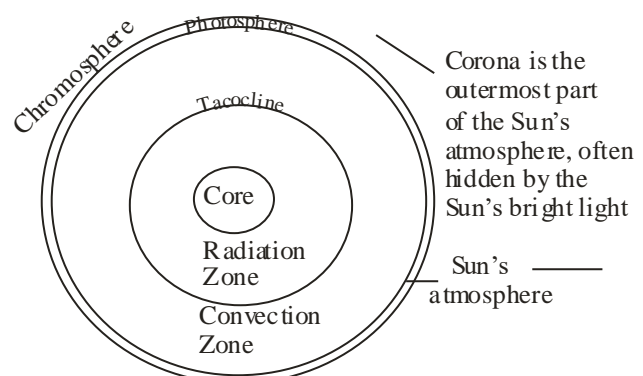


Fig. 2. The accepted structure of our Sun.

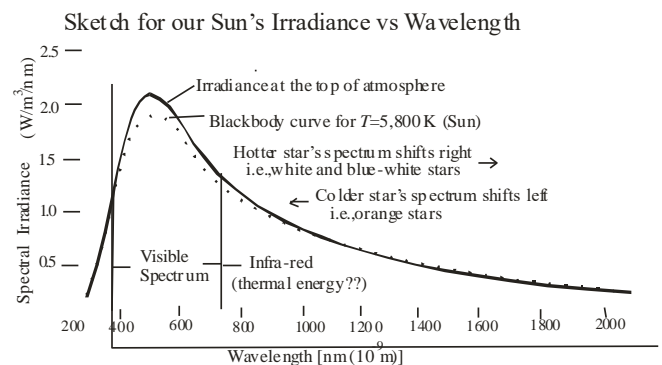


Fig. 3 Our Sun's spectral irradiance.

Our Sun's irradiance (blackbody radiation spectrum) is sketched in Fig. 3. Note that Robitaille has given good narratives concerning the history of our understanding of our Sun [25], [26] along with other articles [27], [28]. Furthermore, the idea of a liquid (or condensed matter) Sun

is not unique to Robitaille's LMH solar model. In his model, our Sun's photosphere is a physical surface of condensed matter comprising metallic hydrogen with a graphite-like layered hexagonal lattice, while the core is metallic hydrogen (body-centered cubic crystallography), as first proposed by Setsuo Ichimaru. Furthermore, Robitaille has presented other arguments as to why the Sun is not be gaseous, which may further interest the reader [22], [23], [25], [26] and about which this author remains undecided.

When contemplating our Sun's blackbody radiation, what might be more troublesome than whether or not our Sun has a physical surface is the traditional association of blackbody radiation with surrounding crystalline matter.

IV. ENCLOSURE

Blackbody radiation emanating from a hole in an enclosed cavity is shown in Fig 1. The accepted interpretation is based upon Kirchhoff's law: "If a space be entirely surrounded by bodies of the same temperature, so that no rays can penetrate through them, every pencil in the interior of the space must be so constituted, in regard to its quality and intensity, as if it had proceeded from a perfectly black body of the same temperature, and must therefore be independent of the form and nature of the bodies, being determined by temperature alone... In the interior therefore of an opaque red-hot body of any temperature, the illumination is always the same, whatever be the constitution of the body in other respects" [29].

According to Kirchhoff an enclosed cavity (see Fig. 1) contains blackbody radiation no matter what. To many it remains a requirement for blackbody radiation from any substance that does not have carbon black's emissivity (unity). However, as earlier pointed out by this author such an enclosure may simply be a local where the shielding from photons emanating from some external source enables one to clearly witness the blackbody radiation. This should equally apply to the traditional conscripts of blackbody radiation, as described by the likes of Kirchhoff and Planck, or to blackbody radiation as described by herein, i.e., radiation from an ensemble of inelastic intermolecular collisions.

In other words, the necessity of a star, e.g. our Sun having an exterior surrounding surface may actually be a false premise, no matter one's interpretation of blackbody radiations. This would certainly be the case if one accepts this author's assertions. Furthermore, any need of a cavity's surrounding matter being crystalline no longer applies once you begin to think in terms of inelastic collisions.

V. ADSORPTION VS RADIATION, AND CARBON BLACK

The notion of carbon black is one where both the absorptivity and emissivity of a material is unity. A corollary of this then becomes that in thermal equilibrium a carbon black material absorbs as much energy, as it emits.

There should be hesitation with the above assertion. Namely, it implies that carbon black absorbs and radiates all frequencies of radiation with 100% efficiency, when the reality is that:

1) It might only adsorb visible light with such efficiency, and still be called black.

2) It does not necessarily radiate the same quantities of energy at all identical frequencies, as it adsorbs.

In order to understand 2), consider a black car parked in sunlight outside at 300 K, i.e. a type of carbon black. The car adsorbs most of the incident visible light, and hence it does not reflect visible light in a manner similar to a white car. Importantly, the black car transforms that visible light into thermal energy and then radiates that energy as a blackbody spectrum whose peak is centered in the infrared ($T=300$ K).

Accordingly, when in thermal equilibrium the black car radiates the same total amount of thermal energy as it adsorbs, but it does not necessarily radiate the same energy spectrum that it adsorbs. Obviously, one cannot assume that the adsorption spectrum is identical to the radiation spectrum for any substance, when in thermal equilibrium.

This further enlightens us to this author's discussion that most of the thermal energy from our Sun resides in the infrared, even though we tend to emphasize the visible parts of that spectrum. The fact that the energy associated with the infrared part of our Sun's spectrum is a linearly decreasing function of frequency/wavelength, clearly helps to explain why our thermodynamic relations tend to be linear functions of temperature [20].

VI. LIGHT BULBS AND INELASTIC COLLISIONS

Accepting that collisions are inelastic, one would then expect a spectrum of photons to be produced by an ensemble of molecules undergoing intermolecular collisions, i.e., a blackbody spectrum. As the matter becomes hotter, the amount of radiation per wavelength increases and the peak wavelength shifts to higher shorter wavelengths (higher frequencies), i.e., higher energy photons.

Consider the incandescent lightbulb with the traditional explanation being that as, the tungsten filament heats, electrons go into an excited state and then continually drop down a state, thus emitting a constant stream of visible photons. If purely based upon electron excitation, one might expect more well-defined spectral lines, than is witnessed in a blackbody radiation spectrum.

The accepted dubious explanation for the general lack of spectral lines is that the tungsten atoms are in various states, within a solid matrix of atoms. Furthermore, the electric fields of the adjacent atoms cause the electrons to possess a vast number of energetic states. These overlapping states then allow for the blackbody spectrum.

Does it not make more sense to simply say that the tungsten molecules vibrate and emit visible photons as a blackbody spectrum due to inelastic collisions? Accepting that inelastic intermolecular collisions create blackbody radiation, then at room temperature (300 K) these photons would have a blackbody spectrum whose peak is centered in the infrared, and hence our eyes would witness nothing.

Reconsidering the traditional explanation at room temperature one may ponder why he/she witnesses no radiation at all. Okay tungsten would still be a matrix of atoms with electrons possessing a vast number of energetic states,

so why no visible emissions? One could argue that it is the elevated temperature, but temperature is a thermodynamics phenomenon not a solid state one, i.e., temperature is associated more with molecular vibrations than electron transitions.

Reconsider the inelastic collision model for blackbody radiation. When passing electricity through the element, its resistance heats the tungsten molecules causing the frequency of emitted photons to increase. Hence, at around 2300 K one starts to witness visible light. This is not limited to tungsten, as it is universal for all condensed matter.

When heated to $T = 2,000$ K to $3,000$ K, the majority of energy given off by the tungsten would still be blackbody whose peak is in the infrared, i.e., 95% of the blackbody spectrum is still thermal energy while the visible part of the spectrum would represent approximately 5%. Thus, explaining why the incandescent light bulb is so inefficient. If one could heat the element to $5,000$ - $10,000$ K then the percentage of visible light emitted would increase hence the efficiency would increase dramatically. Unfortunately, tungsten melts at $3,695$ K, so attaining a significantly higher efficiency tungsten filament light bulb is impossible.

The above explanation avoids the need for electron excitation, which contravenes logic because it is the molecules as a whole and not just the electron per se that is heated. Moreover, it also helps explain why most matter turns red hot when heated, irrelevant of the molecule's electron's configuration. Of course, most matter will melt before it reaches temperatures associated with being white hot, hence would not be suitable for providing man with light.

The removal of the association of a hot body's light emission from that body's electrons bodes well with the universality of both:

- 1) Blackbody radiation, and
- 2) The heat capacities of both condensed matter and gases.

VII. STARS AND INELASTIC COLLISIONS

If our Sun's photons are derived from inelastic collisions, then our sunshine may not depend so much upon the underlying sources of energy (i.e. nuclear fusion [hydrogen into helium] in our Sun's core), but rather upon the thermal energy density in our Sun's outer atmosphere. This should apply whether our Sun's outer layers are deemed as being gaseous, condensed matter, or some combination of both.

The above would certainly explain why the blackbody radiation as emitted by any body is not dependent upon that body's inner workings, but rather upon the thermal energy density of the body's outer layers, as determined by its temperature. It may still take millions of years for the energy produced in the core to reach a star's outer layer but what we generally witness here on Earth is not based upon time nor whether a star's surface is real or imaginary

A sketch of our Sun's spectrum is given in Fig. 3 [20]. It is well accepted that stars hotter than our Sun tend to have a bluer blackbody spectrum, i.e., the spectrum shifts to the right in Fig. 3. Conversely, stars that are cooler than our Sun tend to have spectrums that are redder than our Sun's. i.e., the spectrum shifts to the left in Fig. 3.

Accepting that Stefan-Boltzmann's law is correct, one can infer the star's temperature based upon their spectrum's color. For example, red stars are around 2000 K (e.g., Aldebaran), orange stars are closer to 3000 K (e.g., Arcturus, a.k.a. giant red star), yellow stars are near 4000 K, e.g., Capella, while our Sun's temperature is $5,800$ K, with white stars being warmer at 6000 K (e.g., Sirius A is a blue-white) and blue stars being even hotter i.e., $10,000$ – $40,000$ K.

Of course, based upon our new interpretations, one could now contemplate the different stars' colors as indications of the star's thermal energy density at its outer surface, and how that changes the energetics of the inelastic molecular (inter and intra) collisions at those surfaces.

VIII. BLACKBODY VS TEMPERATURE

As previously stated, the Stefan-Boltzmann law describes the energy emanating from a body associated with its temperature. By thinking in terms of inelastic collisions not only gives one insight into the relationship between matter's emitted spectrum and its temperature, it may also help alter how one views temperature. The new perspective may be that the vibrating molecule's emitted energy determines the temperature that one measures.

Either way, kinetic theory [30], [31] both traditional and that proposed by this author [1], [2] assures us that as one increases the temperature (T) a molecule's vibrational energy as multiples of $kT/2$. Consequentially, as the vibrational energy increases, the energy associated with inelastic collisions increases, therefore the energy associated with the spectrum of emitted energy, as defined by its blackbody radiation, increases. Again, the chicken or the egg argument may be made, as to what is most important a vibrating molecule's temperature or its inelastic collisional kinematics.

It becomes fundamental that blackbody radiation is independent of the state of matter, depending only upon the matter's thermal energy density, which also defines that particular matter's temperature.

Furthermore, a monatomic gas has no vibrational modes, so it only produces radiation through inelastic intermolecular collisions. On the other hand, polyatomic gases and condensed matter both adsorb heat as part of their vibrational energies [1,2]. Such heat is predominately infrared, and those molecules then radiate a blackbody spectrum due to their intramolecular inelastic collisions (around a peak located in the infrared when $T=300$ K).

The above includes homonuclear gases (e.g. oxygen and nitrogen), as is clearly proven by their heat capacities. It must be stated that this author considers that the current science of global warming incorrectly considers that homonuclear molecules are opaque to infrared. This is due to the theoretical/experimental tragedy of running a blank and then subtracting the blackbody radiation centered in the infrared from their analysis [32]. Correcting this remains crucial to man's comprehension of global warming, and possibly our survival here on Earth.

IX. VIBRATING CHARGES

Throughout this paper, the fact that a vibrating charge can produce EM waves has not been challenged. This is because a blackbody spectrum is temperature dependent, hence is better suited to an explanation based upon a spectrum produced by inelastic intermolecular, and/or intramolecular collisions. As previously stated; perhaps, what is often witnessed is from a combination of sources, however in all likelihood the majority of blackbody radiation is a result of inelastic molecular collisions.

X. CONCLUSIONS

It is hard to imagine anyone believing that most collisions, at any scale, are anything but inelastic. Strangely, the sciences wrongly chooses elastic collisions as part of its theoretical basis. This simplifies the math while lending itself to various theoretical over-complications and gross over-sights. Acknowledging that collisions are inelastic might be challenging to those who subscribe to theories whose fundamental basis remain mathematical, e.g., entropy being constructed upon elastic collisions, needs to have its real-world relevance questioned.

Accepting that intermolecular collisions are inelastic starts with this author's rewrite of kinetic theory [1], [2]. It then raises the question as to where the photons created during such inelastic collisions. The conclusion being is that a blackbody radiation spectrum (complete, or a significant part of) is due to inelastic molecular collisions.

Although not clearly stated, the traditional implication is that blackbody radiation from a cavity is a spectrum of photons produced by the surrounding vibrating molecules' oscillating charges. An issue becomes that the universal nature of blackbody radiation is hard to fathom in light of the fact that various materials possess differing charge structures.

Blackbody radiation from incandescent lightbulbs is thought to be due to electrons in the filament (often tungsten) continuously dropping out of an excited state. Although explanations have been devised, they remain weak, as they do not fully explain why there are no spectral lines at any temperature, found in the blackbody radiation from any substance.

When applying the theory that blackbody radiation is due to inelastic molecular collisions to the incandescent lightbulb, one attains a simpler understanding as to why tungsten illuminates with white light, when sufficiently heated, i.e. $T=2,000$ to $3,000$ K. Moreover, one begins to understand why most matter starts producing white light at such temperatures.

Interestingly, one also arrives at an elevated clarity when contemplating the light bulb's efficiency, which increases as the illuminating body approaches $T=10,000$ K. Such a simple explanation cannot be obtained using traditional assertions.

When this theory is applied to stars, it becomes apparent that inelastic intermolecular collisions within our Sun's atmosphere ($T=5,800$ K) create the visible light that governs our lives, thus avoiding the traditional dogmatic issues of blackbody radiation being associated with enclosures in crystalline condensed matter. Importantly, the blackbody theory presented herein can explain what is witnessed,

irrelevant of star's interiors are gaseous, or possess an actual surface.

Of further relevance is the realization that the emission spectrum is not necessarily the same as the adsorption spectrum for any matter in thermal equilibrium. Thermal equilibrium simply means that the total quantity of thermal energy adsorbed equals the total quantity emitted. Not only does this explain why a black car gets hot when in the sunlight but it also provides insight into why most thermodynamic relations are a linear function of temperature.

Furthermore, the realization that an ensemble of inelastic molecular collisions creates a blackbody spectrum, conceptually fits well with this author's "New Thermodynamic" [3]. In other words, we should reconsider how we envision temperature, and thermodynamics in general.

We did not prove beyond a doubt that blackbody radiation is a result of inelastic molecular collisions. We did however show that it forms a simpler theory than what is currently accepted. It is up to you to abide by Occam's razor.

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