SPECIAL REPORT

Forty Lines of Evidence for Condensed Matter — The Sun on Trial: Liquid Metallic Hydrogen as a Solar Building Block

Pierre-Marie Robitaille

Department of Radiology, The Ohio State University, 395 W. 12th Ave, Columbus, Ohio 43210, USA.
robitaille.1@osu.edu

Our Sun has confronted humanity with overwhelming evidence that it is comprised of condensed matter. Dismissing this reality, the standard solar models continue to be anchored on the gaseous plasma. In large measure, the endurance of these theories can be attributed to 1) the mathematical elegance of the equations for the gaseous state, 2) the apparent success of the mass-luminosity relationship, and 3) the long-lasting influence of leading proponents of these models. Unfortunately, no direct physical finding supports the notion that the solar body is gaseous. Without exception, all observations are most easily explained by recognizing that the Sun is primarily comprised of condensed matter. However, when a physical characteristic points to condensed matter, *a postori* arguments are invoked to account for the behavior using the gaseous state. In isolation, many of these treatments appear plausible. As a result, the gaseous models continue to be accepted. There seems to be an overarching belief in solar science that the problems with the gaseous models are few and inconsequential. In reality, they are numerous and, while often subtle, they are sometimes daunting. The gaseous equations of state have introduced far more dilemmas than they have solved. Many of the conclusions derived from these approaches are likely to have led solar physics down unproductive avenues, as deductions have been accepted which bear little or no relationship to the actual nature of the Sun. It could be argued that, for more than 100 years, the gaseous models have prevented mankind from making real progress relative to understanding the Sun and the universe. Hence, the Sun is now placed on trial. Forty lines of evidence will be presented that the solar body is comprised of, and surrounded by, condensed matter. These 'proofs' can be divided into seven broad categories: 1) Planckian, 2) spectroscopic, 3) structural, 4) dynamic, 5) helioseismic, 6) elemental, and 7) earthly. Collectively, these lines of evidence provide a systematic challenge to the gaseous models of the Sun and expose the many hurdles faced by modern approaches. Observational astronomy and laboratory physics have remained unable to properly justify claims that the solar body must be gaseous. At the same time, clear signs of condensed matter interspersed with gaseous plasma in the chromosphere and corona have been regrettably dismissed. As such, it is hoped that this exposition will serve as an invitation to consider condensed matter, especially metallic hydrogen, when pondering the phase of the Sun.

The Sun is a world so different from our own . . . However [relative to understanding its structure], *one must not lose heart; over the past few years science has made a lot of progress, and those who come after us will not fail to make even more.*

Father Angelo Secchi, S.J., 1875 [1, p. 300, V. I]*

1 Introduction

A long time ago, men like Gustav Kirchhoff, Johann Zöllner, William Thomson (Lord Kelvin), and James Jeans viewed the photosphere (or the solar body) as existing in the liquid state [2, 3]. Despite their stature, scientists, since the days of Herbert Spencer and Angelo Secchi, slowly drifted towards the concept that the Sun was a ball of gas surrounded by condensed matter [2, 3].†

Others, of equal or greater prominence, including August Ritter, Jonathan Lane, Franz Schuster, Karl Schwarzschild, Arthur Eddington, Subrahmanyan Chandrashekhar, and John Bahcall, would have their chance to speak [2, 3]. The Sun became a fully gaseous plasma.

As a consequence, the gaseous Sun has imbedded itself at the very foundation of astronomy. Few would dispute that

*Translations from French were executed by the author.

†In the mid-1800s, five great pillars had given birth to the gaseous Sun: 1) Laplace's Nebular Hypothesis, 2) Helmholtz' contraction theory, 3) Cagniard de la Tour's critical phenomena and Andrew's critical temperatures, 4) Kirchhoff's formulation of his law of thermal emission, and 5) the discovery of pressure broadening in gases. Each of these has previously been addressed in detail [2].

the Sun is a gas and that our understanding of all other stars and the entire universe, is inherently linked to this reality. Therefore, any endeavor to touch the phase of the Sun must be viewed as an attempt to reformulate all of astronomy.

Yet, when astrophysics remained a young science, observational astronomers, such as James Keeler, Edwin Frost, and Charles Abbot [4], objected to the theoretical basis for a gaseous Sun. August Schmidt was the first to mathematically dismiss the solar surface as illusion. Speaking of him, Charles Abbot, the director of the Smithsonian Observatory would write, *"Schmidt's views have obtained considerable acceptance, but not from observers of solar phenomena"* [5, p. 232]. In 1913, Charles Maunder made the point even more forcefully, *"But under ordinary conditions, we do not see the chromosphere itself, but look down through it on the photosphere, or general radiating surface. This, to the eye, certainly looks like a definite shell, but some theorists have been so impressed with the difficulty of conceiving that a gaseous body like the Sun could, under the conditions of such stupendous temperatures as there exist, have any defined limit at all, that they deny that what we see on the Sun is a real boundary, and argue that it only appears so to us through the effects of the anomalous refraction or dispersion of light. Such theories introduce difficulties greater and more numerous than those that they clear away, and they are not generally accepted by the practical observers of the Sun"* [6, p. 28]. Alfred Fowler, the first Secretary of the International Astronomical Union, shared these views, *"The photosphere is thus regarded as an optical illusion, and remarkable consequences in relation to spots and other phenomena are involved. The hypothesis appears to take no account of absorption, and, while of a certain mathematical interest, it seems to have but little application to the actual Sun"* [7].

With time, however, the voices of the observational astronomers were silenced by the power and elegance of the mathematical arguments [2, 3]. Those who could not follow sophisticated theory could no longer become professional astronomers. At Cambridge, the Mathematical Tripos became and remained an accepted path to a Ph.D. degree in astronomy [8]. Theory [9–14],* rather than observation, came to dictate the phase of the Sun and all solar phenomena were explained in terms of a gaseous entity.

As gases are unable to support structure, additional means were adopted to explain solar observations. Magnetic fields became the solution to every puzzle [12], even though gases are incapable of their generation.† Over time, theoretical approaches claimed one victory after the next, until it seemed as if the Standard Solar Models [11, 13, 14] were unshakable. Gases were inappropriately endowed with all of the properties of condensed matter.

In reality, a closer examination would have revealed that many theoretical achievements were inapplicable. Some of the difficulties stemmed from improper experimental conclusions. The universality of several laws [15–20], on which the entire solar framework rested [9, p. 27–58], was the product of faulty assumptions [21–24]. These errors were introduced when theoretical physics remained in its infancy. But now, they were governed by other branches of physics (i.e. blackbody radiation and condensed matter physics [15–20, 25]), not by astronomy. The most pressing problems were never properly solved by the physics community [21–24].

Solar theory was replete with oversights and invalid assumptions, but the shortcomings would be extremely difficult to detect. Problems which were 'solved 100 years ago' still lurked in the background [19,20]. Too much forward progress was desired with too little attention paid to the road traveled. Most viewed that only a few minor problems remained with gaseous equations of state [13,14]. Evidence that the Sun was not a gas was dismissed with complex schemes often requiring the suspension of objectivity.

Nonetheless, many lines of evidence had revealed that the body of the Sun must be comprised of condensed matter (see Table I). Slowly, arguments initially advanced by men like Gustav Kirchhoff [26] and James Jeans [27, 28] began to reemerge. Moreover, they were joined by an arsenal of new observations. Today, at least forty proofs can be found disputing the gaseous nature of the Sun. There are surely more to be discovered.‡ Conversely, not one direct proof exists that the body of the Sun must be considered a gaseous plasma.

It is clear that the lines of evidence for condensed matter which are contained herein§ are worthy of a cohesive discussion. For the purpose of this presentation, they are subdivided and reorganized into seven broad categories: 1) Planckian, 2) spectroscopic, 3) structural, 4) dynamic, 5) helioseismic, 6) elemental, and 7) earthly. Each proof will be discussed relative to the liquid metallic hydrogen (LMH) model [36, 39, 47, 48] wherein condensed hydrogen, pressurized in the solar interior, assumes a graphite-like lattice on the photosphere [39, 40, 45, 48], a more metallic nature in sunspots and faculae [40,45,52], a diffuse presence in a somewhat cool

*Eddington's mass-luminosity relationship [9, p. 145–179] stands as one of the great triumphs of the gaseous models. Today, this finding is well established in observational astronomy and Eddington's derivation is worthy of a detailed treatment. Due to space limitations, the topic will not be addressed herein. Suffice it to state that Eddington's derivation was dependent on the validity of Kirchhoff's law and no effort has been made to account for the relationship if the stars were made of condensed matter. At the same time, it must be noted that through the mass-luminosity relationship, an observation linked to distant objects, came to dictate the phase of the Sun. The relationship is not contingent on the behavior of the Sun itself, although the latter does lie on the main sequence of the stars.

†Magnetic fields are the product of underlying microscopic structure in condensed matter. As such, whenever a magnetic field is generated on Earth, condensed matter must be involved, either to directly generate it, or to cause the ordered flow of charge.

‡Solar astronomers, upon further consideration, will recognize that their own subject areas might also provide additional lines of evidence. With time, these complimentary proofs will eventually surface.

§The author presents a complete list of his relevant works [2–4, 29–62] in order to facilitate the study of these problems.

I. Planckian Lines of Evidence §2 p. 92	**IV. Dynamic Lines of Evidence §5 p. 118**
1. Solar Spectrum §2.3.1 p. 95	25. Surface Activity §5.1 p. 118
2. Limb Darkening §2.3.2 p. 97	26. Orthogonal Flows §5.2 p. 121
3. Sunspot Emissivity §2.3.3 p. 98	27. Solar Dynamo §5.3 p. 121
4. Granular Emissivity §2.3.4 p. 100	28. Coronal Rain §5.4 p. 122
5. Facular Emissivity §2.3.5 p. 101	29. Coronal Loops §5.5 p. 123
6. Chromospheric Emissivity §2.3.6 p. 102	30. Chromospheric Condensation §5.6 p. 124
7. K-Coronal Emissivity §2.3.7 p. 103	31. Splashdown Events §5.7 p. 125
8. Coronal Structure Emissivity §2.3.8 p. 103	32. Solar Winds and the Solar Cycle §5.8 p. 125
II. Spectroscopic Lines of Evidence §3 p. 104	**V. Helioseismic Lines of Evidence §6 p. 127**
9. UV/X-ray Line Intensity §3.1 p. 104	33. Solar Body Oscillations §6.1 p. 127
10. Gamma-Ray Emission §3.2 p. 104	34. Mass Displacement §6.2 p. 128
11. Lithium Abundances §3.3 p. 105	35. Higher Order Shape §6.3 p. 129
12. Hydrogen Emission §3.4 p. 106	36. Tachocline and Convective Zones §6.4 p. 129
13. Elemental Emission §3.5 p. 108	37. Solar Core §6.5 p. 129
14. Helium Emission §3.6 p. 109	38. Atmospheric Seismology §6.6 p. 129
15. Fraunhofer Absorption §3.7 p. 112	
16. Coronal Emission §3.8 p. 112	
III. Structural Lines of Evidence §4 p. 114	**VI. Elemental Lines of Evidence §7 p. 129**
17. Solar Collapse §4.1 p. 114	39. Nucleosynthesis §7.1 p. 129
18. Density §4.2 p. 115	
19. Radius §4.3 p. 115	
20. Oblateness §4.4 p. 115	**VII. Earthly Lines of Evidence §8 p. 130**
21. Surface Imaging §4.5 p. 116	40. Climatic §8.1 p. 131
22. Coronal Holes/Rotation §4.6 p. 116	
23. Chromospheric Extent §4.7 p. 117	
24. Chromospheric Shape §4.8 p. 118	

Table 1: Forty Lines of Evidence for Condensed Matter — The Sun on Trial.

corona [57, 58, 60], and a solid character in the core [50].*

Of these lines of evidence, the thermal proofs will always remain central to understanding the condensed nature of solar material. They are tied to the most important questions relative to light emission [15–20] and have the ability to directly link physical observation to the presence of a vibrational lattice, a key aspect of all matter in the condensed phase [21–24]. Hence, the discussion begins with the thermal lines of evidence, as inherently related to blackbody radiation [15–25, 63] and to the earliest scientific history of the Sun [2, 3].

*The model adopts a liquid state for the surface of the Sun, as this is in keeping with macroscopic observations. However, an extended structural lattice, not simply a random assembly of degenerate atoms, is required, as demonstrated in §2. Of course, on the scale of solar dimensions, even a material with the rigidity of a solid on Earth (i.e. with a high elastic modulus), might well appear and behave macroscopically as a liquid on the photosphere.

2 Planckian (or Thermal) Lines of Evidence

The Sun emits a spectrum in the visible and infrared region of the electromagnetic spectrum (see Fig. 1) whose detailed analysis provides a total of eight lines of evidence relative to the presence of condensed matter.† For gaseous models, solar emission must be explained using the most complex of schemes, resting both on the validity of Kirchhoff's law of thermal emission [15, 16] and on the *'solar opacity problem'* [42].

Agassi reminds us that *"Browsing through the literature, one may find an occasional use of Kirchhoff's law in some*

†These proofs require the longest descriptions, as they touch many concepts in physics. Since they deal with thermal phenomena, they can also be referred to as the *'Planckian'* lines of evidence, in recognition of Max Planck's contribution to this area of physics [19, 20]. Beyond physics, Max Planck's philosophical writings (see references in [64]) and personal conduct [65], despite the evil of his times, have much to offer to modern society.

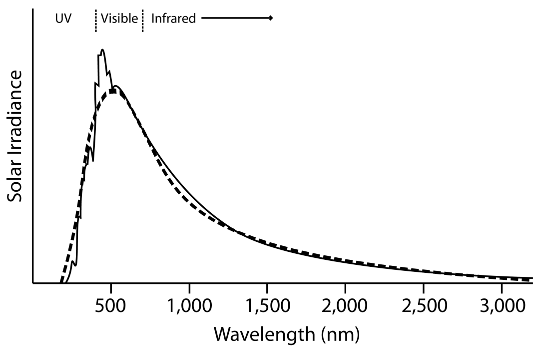

Fig. 1: Schematic representation of the visible spectrum of the Sun (adapted from Fig. 1–3 in [66]). To a first approximation, the solar spectrum is very nearly identical to that of a blackbody with a temperature of ~5,800 K (dashed line).

experimental physics, but the only place where it is treated at all seriously today is in the astrophysical literature" [63]. In reality, it would not be an overstatement to argue that Kirchhoff's law [15, 16] constitutes the very core of accepted solar theory. Any problems with its formulation would send shock waves not only throughout stellar astrophysics, but to every corner of modern astronomy. Hence, the discussion with respect to the thermal lines of evidence commences with a review of Kirchhoff's law [15, 16] and of blackbody radiation [17–25]. This will be followed by an overview of these principles, as applied to the Sun and the resulting solar opacity problem [42].

2.1 Blackbody Radiation and Kirchhoff's Law

The author has previously stated that, *"Kirchhoff's law is one of the simplest and most misunderstood in thermodynamics"* [24].* Formulated in 1860 [15,16], the law was advanced to account for the light emitted from objects in response to changes in temperature. Typically, in the mid-1800s, the objects were black, as they were covered with soot, or black paint, for best experimental results [21, 23, 24]. Thus, this field of research became known as the study of *'blackbody radiation'* [21, 23, 24]. Kirchhoff attempted to synthesize an overarching law into this area of physics in order to bring a certain unification to laboratory findings. At the time, physics was in its infancy and theorists hoped to formulate laws with *'universal'* consequences. Such was Kirchhoff's goal when his law of thermal emission was devised.

The heart of Kirchhoff's law states that, *"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 the temperature alone . . . In the interior therefore of an opake red-hot body of any temperature, the illumination is always the same, whatever be the constitution of the body in other respects"* [16, §16].†

Blackbody radiation was governed strictly by the temperature and the frequency of interest. *The nature of the walls was irrelevant*. Kirchhoff introduced the idea that blackbody radiation somehow possessed a *'universal'* significance and was a property of all cavities [15, 16].

Eventually, Max Planck [19, 20] provided a mathematical form for the spectral shape of blackbody emission sought by Kirchhoff [15, 16]. Kirchhoff's law became ingrained in Planck's formulation [20, §24–§62]. By extension, it also became an integral part of the laws of Wien [17] and Stefan [18], as these could be simply derived from Planck's equation [20, §31–§60]. In turn, the laws of radiation, came to form the very foundation of the gaseous models (see e.g. [9, p. 27–58]).

Since blackbody radiation was thought to be of a *'universal'* nature and *independent of the nature of the walls*, Max Planck, was never able to link his equation to a direct physical cause [21, 23, 24].‡ He spoke of any such attempt as a *'hopeless undertaking'* [20, §41]. In this respect, blackbody radiation became unique in physics. Planck's equation was not linked to anything in the material world, as Kirchhoff's law [15, 16] had dictated that the process was detached from physical causality [20, 21].

With his law, Gustav Kirchhoff was informing the physics community that the light emitted by an object will always correspond to the same *'universal'* spectrum at a given temperature, provided that the object be enclosed and the entire system remain at thermal equilibrium. Any enclosure contained the same blackbody radiation. The nature of the enclosure was not relevant to the solution, given that it was truly opaque. Perfectly reflecting enclosures, such as those made from silver, should function as well as perfectly absorbing enclosures made from graphite or coated with carbon black.

In reality, Kirchhoff erred in believing that the nature of

*A detailed series of publications related to the analysis of Kirchhoff's law has previously appeared. These can be consulted by those who seek a more extensive discussion of the subject matter (see [21–24]).

†Note how this last sentence immediately implied that, if the solar interior could be viewed as enclosed, then the radiation existing within it must be of the same form (intensity versus frequency) as that emitted by a blackbody at the temperature in question.

‡In processes where light is emitted, there are five aspects to consider: 1) the physical setting, 2) separate energy levels created in this setting, 3) a transition species which will make use of these energy levels, 4) the production of a photon, and 5) an equation. For instance, for Lyman-α radiation these correspond to 1) the hydrogen atom, 2) the two electronic orbitals involved in the transition — principle quantum numbers N=2 and N=1, 3) the electron as the transition species, 4) the Lyman-α emission at 1216Å, and 5) the Rydberg formula. Alternatively, in speaking of the proton nuclear magnetic resonance line from water, these correspond to 1) the hydrogen atoms of the water molecules placed in a magnetic field, 2) the hydrogen nuclear spin up or spin down states, 3) the hydrogen nuclear spin as a transition species, 4) the hydrogen line at 4.85 ppm, and 5) the Larmor equation. Analogous entries can be made for any spectroscopic process in physics, with the exception of blackbody radiation. In that case, only the 4th and 5th entries are known: 4) the nature of the light and 5) Planck's equation [21].

the enclosure did not matter [21–24]. Perfectly reflecting enclosures manifest the radiation of the objects they contain, not blackbody radiation (see [22] for a proof). To argue otherwise constitutes a violation of the First Law of Thermodynamics. Furthermore, if Kirchhoff's law was correct, any enclosed material could serve as an experimental blackbody. But, laboratory blackbodies are known to be extremely complex devices, typically involving the use of specialized *'nearly perfectly absorbing'* materials over the frequencies of interest.*

Max Planck believed that *"... in a vacuum bounded by totally reflecting walls any state of radiation may persist"* [20, §61]. In itself, this was contrary to what Kirchhoff had stated, as noted above, *"... In the interior therefore of an opake red-hot body of any temperature, the illumination is always the same, whatever be the constitution of the body in other respects"* [16, §16]. Throughout his text on thermal radiation [20], Max Planck repeatedly introduces a *'small carbon particle'* to ensure that the radiation he was treating was truly black [21, 23]. He viewed the particle as a *catalyst* and believed that it simply accelerated the move towards black radiation. In reality, he had introduced a perfect absorber/emitter and thereby filled the cavity with the radiation desired (see [22] for a proof). If Kirchhoff's law was correct, this should not be necessary. The carbon particle was much more than a simple catalyst [21, 23].

Another repercussion to Kirchhoff's statement was the belief that objects could radiate internally. In fact, Planck would use this approach in attempting to derive Kirchhoff's law (see [20, p. 1–45]).† Yet, conduction and/or convection properly govern heat transfer within objects, not internal radiation. Thermal radiation constitutes an attempt to achieve equilibrium with the outside world.

The idea that all opaque enclosures contain blackbody radiation was demonstrably false in the laboratory and Kirchhoff's law of thermal emission, invalid [21–24].‡ Rather, the best that could be said was that, at thermal equilibrium and in the absence of conduction or convection, the absorption of radiation by an object was equal to its emission. This was properly formulated by Balfour Stewart in 1858, one year before Kirchhoff developed his own law [22, 25].

*For an extensive list of references on laboratory blackbodies and the materials used in their preparation, see [23].

†In his derivation, Planck did not permit his volume-elements to reflect light [20, p. 1–45]. As a result, all these elements became perfectly absorbing and he was able to obtain Kirchhoff's law. However, had he properly included reflection, he would have convinced himself that Kirchhoff's law was invalid (see [21–24] for a complete discussion).

‡One cannot expect scientists to revisit the validity of every law upon which they shall base their work. As such, if 20th century astronomers committed a misstep in applying Kirchhoff's law to the Sun, it is not at all clear how this could have been prevented. Indeed, when the author was first considering these problems, he actually believed that Kirchhoff's law was valid (i.e. [29]), but that the Sun simply failed to meet the requirements set forth by enclosure. It was only later, following an extensive review of blackbody radiation [21–24], that he came to realize that there was an error in the law itself.

The universality which Kirchhoff sought was not present. Regrettably, Max Planck had embraced this concept and, as a direct consequence, blackbody radiation was never linked to a direct physical cause. Tragically, the astrophysical community would come to believe that blackbody radiation could be produced without the presence of condensed matter. Upon this *ex nihilo* generation, it built the foundations of a gaseous Sun [9, p. 27–58] and the framework of the universe.

2.2 Kirchhoff's Law, Solar Opacity, and the Gaseous Models of the Sun

Given thermal equilibrium, Kirchhoff's belief that all opaque enclosures contained blackbody radiation had profound consequences for astronomy. If the Sun was considered to be an enclosure operating under thermal equilibrium, then by Kirchhoff's law, it was filled with blackbody radiation (e.g. [9, p. 27–58]). Nothing was required to produce the radiation, other than adherence to Kirchhoff's condition. Even so, use of the laws of thermal emission [15–20] explicitly required the presence of thermal equilibrium in the subject of interest (i.e. conduction and convection must not be present [21–24]).

As for the Sun, it operates far out of equilibrium by every measure, emitting a large amount of radiation, but absorbing essentially none. Furthermore, it sustains clear differential convection currents on its surface, as reported long ago by Carrington [67, 68]. Consequently, how could the proponents of the gaseous models justify the use of the laws of thermal emission to treat the interior of the Sun [9, 13, 14]? How could an object like the Sun be considered enclosed?

Arthur Eddington viewed the Sun as filled with radiation which was essentially black. For him, the Sun acted like a slowly leaking sieve [9, p. 18]. In speaking of the application of Stefan's law [18] to the solar interior, Eddington argued, *"To a very high degree of approximation the last two results are immediately applicable to the interior of a star. It is true that the radiation is not in an ideal enclosure with opaque walls at constant temperature; but the stellar conditions approach the ideal far more closely than any laboratory experiments can do"* [9, p. 99–100]. He justified these statements based on the *very opaque* nature of stellar material which he inferred by considering a distant star, Capella [9, p. 100].

Stefan's law codified a fourth power dependence on temperature (T^4) [18]. At the same time, the gaseous Sun was thought to sustain a core temperature of roughly 1.6×10^7 K [13, p. 9] while displaying an apparent surface temperature of only 6,000 K. Therefore, application of Stefan's law [18] to imaginary concentric spheres [13, p. 2] located in the interior of the Sun would result in a great deal more photons produced in the core than ever emitted by its surface. Through the application of such logic, the Sun could be viewed as a slowly leaking sieve and essentially perfectly enclosed. Eddington inferred that the opacity, or ability to absorb a photon, within the Sun was extremely elevated. Under these circumstances, light produced in the solar interior could not travel very far before being absorbed (see [9, p. 100] and [14, p. 185–232]).*

Arthur Milne argued that the interior of a star could be viewed as being in *local thermal equilibrium*, thereby insisting that Kirchhoff's law could be applied within the Sun. Speaking of the solar interior, he stated, *"If the atoms are sufficiently battered about by colliding with one another, they assume a state (distribution of stationary states) characteristic of thermodynamic equilibrium at temperature T"* [69, p. 81–83]. Unfortunately, these words describe the conditions required for the onset of conduction [70]. Thermal equilibrium could never exist at the center of the Sun, as the setting prevailing at the core would facilitate a non-radiative process [21–24].†

Max Planck has clearly stated that thermal equilibrium can only exist in the absence of all conduction, *"Now the condition of thermodynamic equilibrium requires that the temperature shall be everywhere the same and shall not vary with time ... For the heat of a body depends only on the heat radiation, since on account of the uniformity in temperature, no conduction of heat takes place."* [20, §24]. That is why he insisted that the walls of the enclosure be rigid (e.g. [20, §24–25]), as no energy must be carried away through the action of the momentum transfer which accompanies collisions. Accordingly, Milne's arguments, though they rest at the heart of the gaseous solar models, are fallacious. It is inappropriate to apply Stefan's law to the interior of the Sun, as conductive forces violate the conditions for enclosure and the requirements for purely radiative heat transfer.‡

In his treatise on heat radiation, Planck warned against applying the laws of thermal emission directly to the Sun, *"Now the apparent temperature of the Sun is obviously nothing but the temperature of the solar rays, depending entirely on the nature of the rays, and hence a property of the rays and not a property of the Sun itself. Therefore it would be not only more convenient, but also more correct, to apply this notation directly, instead of speaking of a fictitious temperature of the Sun, which can be made to have meaning only by the introduction of an assumption that does not hold in reality"* [20, §51]. Planck must have recognized that the Sun possessed convection currents on its surface [41], as Carrington's discovery [67] would have been well-established throughout scientifically educated society.

To further complicate matters, astrophysics must create sufficient opacity in the Sun. Opacity acts to contain and shift the internal radiation essential to the gaseous models. It has been said that absorption of radiation in the solar interior takes place through the summation of innumerable processes (including bound-bound, bound-free, free-free, and scattering reactions [14, p. 185–232]). Such a hypothesis constitutes the *'stellar opacity problem'*.§ The blackbody spectrum which could be produced in the laboratory using simple materials like graphite, soot, or metal-blacks [21–24], at once required the summation of a large set of processes which were not known to contribute to the production of the blackbody spectrum on Earth [41, 42]. The central problem for gas models is not that the Sun sustains clear convection at the level of the photosphere, nor that inferred conduction exists at its core. Rather, it was that Kirchhoff's law was not valid and that Planck's equation had not been linked to the physical world [21–24]. The laws of thermal emission could not be applied to the Sun. It was not reasonable to account for the production of a blackbody spectrum using opacity calculations which depended on processes unrelated to thermal emission [42]. The production of blackbody radiation required much more than imaginary enclosures. It required the presence of nearly perfectly absorbing condensed matter, as well-demonstrated by all laboratory experiments over the course of more than 200 years (see [21–24] and references therein).

2.3 The Eight Planckian Lines of Evidence

The eight Planckian (or thermal) lines of evidence, on their own, provide sufficient proof that the Sun is comprised of condensed matter. Each of these proofs includes two components 1) a discussion of some aspect of thermal radiation, and 2) the associated structural implications. It has been well-established in experimental physics that the thermal emissivity of a material is directly linked to its structure [71]. Furthermore, condensed matter is known to possess varying directional emissivities which play a key role in understanding the structures associated with the Sun, including the degree to which one might infer that they are metallic [66, 72, 73].

2.3.1 Solar Spectrum #1

The blackbody lineshape of the solar spectrum (see Fig. 1) has been known since the days of Samuel Langley (see [74, Plate 12 and 21] and [75, Plate IV]).¶ Still, though astrophysics

*Eddington concluded that *"the stars on the main series possess nearly the same internal temperature distribution"* and inferred core temperatures in the millions of degrees [9, p. 177–178]. Given his belief that the laws of thermal emission [15–20] could be applied to the core of the stars, the temperatures he inferred would result in the production of photons with X-ray energies. Over thousands of years, these photons would slowly work their way out to escape at the photosphere. But as they traveled to the surface, they would slowly lose energy and become shifted to ever lower frequencies. Finally, upon reaching the surface, they would emit in the visible region of the electromagnetic spectrum. To accomplish the feat, the gas models required that perfect and gradual changes in opacity enabled a blackbody spectrum produced at X-ray frequencies to be slowly converted to one existing in white light. The issue has previously been addressed by the author [3, 36, 42] and provides an example where accepted science required the suspension of disbelief.

†The density at the center of the Sun is believed to approach 150 g/cm^3 [14, p. 483], a value compatible with conductive solids on Earth.

‡The Sun is known to possess powerful magnetic fields and a solar dynamo. Their existence strongly argues for conduction within condensed matter (see [35, 39] and §5.3).

§The author has previously addressed the stellar opacity problem [42].

¶The first Planckian proof [45] was initially treated in [29, 35, 36, 42, 43].

has tried to explain the production of this light for nearly 150 years [2, 3], little real progress has been made in this direction. As demonstrated in Section 2.2, the gaseous models fail to properly account for the occurrence of the solar spectrum. Gases are unable to emit a continuous spectrum. Rather, they emit in bands (see [21,70] and references therein). Even when pressure broadened, these bands cannot produce the blackbody lineshape. Moreover, when gases are heated, their emissivity can actually drop [21,70], in direct contradiction of Stefan's law [18]. Under these circumstances, the answer cannot be found in the gaseous state. One must turn to condensed matter.

Throughout history, the production of a blackbody spectrum [21, 23, 24] has been facilitated by the use of graphite [76–84] or soot. For this reason, even after the formulation of Kirchhoff's law, astronomers envisioned that graphite particles floated on the surface of the Sun [2, 3]. Hastings recognized that the solar surface was too hot to permit the existence of carbon in the condensed state [85]. He noted that *"Granting this, we perceive that the photosphere contains solid or liquid particles hotter than carbon vapor, and consequently not carbon"* [85]. As a result, in 1881, he suggested that *"... the substance in question, so far as we know it, has properties similar to those of the carbon group"* [85]. Hastings wanted something which had the physical characteristics of graphite, especially related to emissivity. Yet, the only aspect of graphite which could contribute to its emissive characteristics was its lattice structure. He was indirectly searching for a material which might share the lattice arrangement known to exist in graphite (see Fig. 2), but which might likewise be reasonably expected to exist on the surface of the Sun.

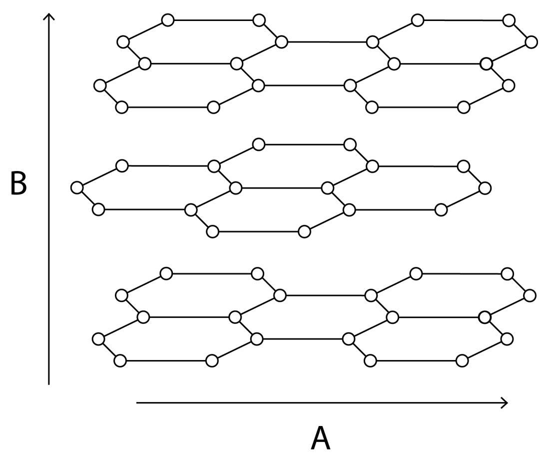

Fig. 2: Schematic representation of the layered hexagonal lattice found in graphite (adapted from Fig. 1 in [48]).

Eventually, Cecilia Payne determined that the stars were largely made of hydrogen [86] and Henry Norris Russell [87] extended the conclusion to the Sun.* Whatever was responsible for the thermal spectrum had to be composed of hydrogen.

Then, in 1935, a seminal work appeared which had the potential to completely alter our understanding of the stars [36, 39]. Eugene Wigner (Nobel Prize, Physics, 1963) and H.B. Huntington [88], proposed that at sufficient pressures, hydrogen could become metallic. More importantly, they would make a direct link between the structure of metallic hydrogen and that of graphite itself, *"The objection comes up naturally that we have calculated the energy of a body-centered metallic lattice only, and that another metallic lattice may be much more stable. We feel that the objection is justified. Of course it is not to be expected that another simple lattice, like the face-centered one, have a much lower energy, — the energy differences between forms are always very small. It is possible, however, that a layer-like lattice has a much greater heat of formation, and is obtainable under high pressure. This is suggested by the fact that in most cases of Table I of allotropic modifications, one of the lattices is layer-like[1]... "* [88]. The footnote in the text began, *"Diamond is a valence lattice, but graphite is a layer lattice ... "* [88].

With time, Brovman et al. [89] would propose that metallic hydrogen might be metastable. Like diamonds, it would require elevated pressures for formation, but remain stable at low pressures once synthesized. Neil Ashcroft and his group hypothesized that metallic hydrogen might be metastable between its solid and liquid forms [90, 91].

Metallic hydrogen remains elusive in our laboratories (see [39, 92] for recent reviews). Nonetheless, this has not prevented astrophysics from invoking its existence within brown dwarfs and giant planets [93–95], or even in neutron stars [96]. In fact, based on expected densities, temperatures, and elemental abundances obtained using the gaseous models for the solar core, metallic hydrogen has been said to exist at the center of the Sun [97–99].†

In previous astrophysical studies [93–99], thermal emission has not guided the selection of the form which metallic hydrogen would adopt. As a result, they have sidestepped the layered graphite-like structure first suggested by Wigner and Huntington [88]. Nonetheless, it seems clear that metallic hydrogen, based on the inferred solar abundance of hydrogen [86, 87] and extensive theoretical support (see [39, 92] for

*See [47] for a detailed discussion on the composition of the Sun.

†Setsuo Ichimaru was primarily concerned with nuclear reactions in high density plasmas [97–99]. His work on the solar core is based on assumptions for the composition of the solar interior [97, p. 2] which are derived from the gaseous models, *"In the Sun ... the mass density and the temperature are estimated to be 156 g/cm^3 and 1.55x10^7, respectively. The mass fraction of hydrogen near the core is said to be 0.36 and thus the mass density of metallic hydrogen there is 56.2 g/cm^3"* [98, p. 2660]. Ichimaru places specific emphasis on the One-Component Plasma (OCP) [97, pp. 103 & 209]. He assumed that the lattice points were those of a body-centered cubic [97]. The body-centered cubic is a solid structure. Its existence within the Sun had not been justified beyond inferred densities. Ichimaru's assumptions would have been easily supported by recent seismological evidence which demonstrates that the solar core experiences solid body rotation (see [50] and §6.5 in this work). His supposition has important consequences for driving nuclear reactions within the Sun (see [44, 48] and §7.1 in this work).

reviews), constitutes an ideal building material for the entire Sun which is appropriate for 21st century thought.

Thus, theoretical condensed matter physics unknowingly provided astronomy with everything needed to explain the origin of the thermal spectrum (see Fig. 1). Payne and Russell had determined that the Sun was composed of hydrogen [86, 87]. Under the enormous pressures which existed in the solar interior, Wigner and Huntington [88] allowed that this hydrogen could be converted to the metallic state and adopt the lattice structure of graphite. Work by Brovman et al. [89] enabled metallic hydrogen, formed under high pressure conditions within the solar interior, to be metastable at the surface. Thermal emission could then result from lattice vibrations [21], occurring within layered metallic hydrogen, much like what occurs with graphite on Earth.

In contrast to the gaseous models, where photons take millions of years to escape from the solar core [9], in a liquid metallic hydrogen (LMH) Sun, light can be instantly produced at the level of the photosphere, using mechanisms identical to those found within graphite. Complex changes in internal solar opacities are not required [42]. The solar spectrum can be explained without recourse to unsuited gases [21, 70], imaginary enclosures [9], dismissal of observed conduction [69] and convection [67, 68], the need for local thermal equilibrium [69], or Kirchhoff's erroneous law [15, 16]. The conjecture that solar thermal emission is produced by hydrogen in the condensed state on the surface of the Sun is simpler than any scheme brought forth by the gaseous models. Furthermore, it unifies our understanding of thermal emission in the stars with that of laboratory models on Earth. But most importantly, it results in the incorporation of a structural lattice directly onto the photosphere, providing thereby a basis upon which every other physical aspect of the Sun can be directly explained — from the presence of a true surface to the nature of all solar structures. Hydrogen's ability to exist as condensed matter within the solar body, photosphere, chromosphere, and corona, appears all but certain. The remainder of this work should help to further cement this conclusion.

2.3.2 Limb Darkening #2

According to Father Angelo Secchi, while Galileo denied the existence of limb darkening (see Figs. 3, 4), the phenomenon had been well established by Lucas Valérius of the Lincei Academy, *"...the image of the Sun is brighter in the center than on the edges."* [1, p. 196, V. I].*

In 1902, Frank Very demonstrated that limb darkening was a frequency dependent phenomenon [101] which he attributed to scattering in the solar atmosphere and reflection with carbon particles.†

Very's study of solar emission [101] eventually led to the *law of darkening* initially developed by Karl Schwarzschild

Fig. 3: Image of the Sun displaying how the intensity of the disk decreases towards the limb [100]. Note this image was described as follows, *"Sunspot group in context. The diameter of the Sun is 100 times larger than the diameter of the Earth. This image was recorded with our finder telescope at about the same time as the 15 July images and movies. Target: The Sun; Date: 15 Jul 2002"*. It is reproduced herein thanks to the generosity of the Royal Swedish Academy of Sciences (www.solarphysics.kva.se/NatureNov2002/press_images_eng.html — accessed online 9/15/2013). The SST is operated on the island of La Palma by the Institute for Solar Physics of the Royal Swedish Academy of Sciences in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias.

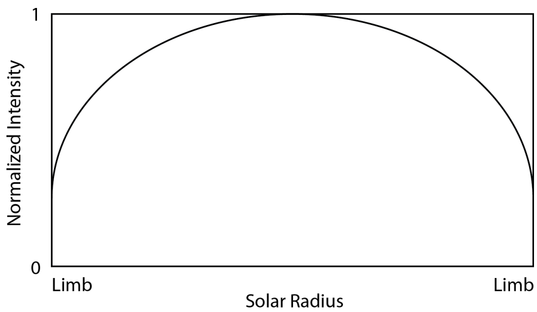

Fig. 4: Schematic representation of the white light intensity variation across the solar disk which is responsible for visible limb darkening. The extent of intensity variation is frequency dependent [101].

[102], whereby the observed phenomenon could be explained by relying on the assumption that radiative equilibrium existed within the stars. Once again, this was viewed as a great triumph for gaseous models (see [3] for additional details).

Arthur Eddington would come to adopt Milne's treatment [103] of the *law of darkening* [9, p. 320–324]. However, all of these approaches shared a common flaw: they were based on the validity of Kirchhoff's law [15, 16]. Karl Schwarzschild's derivation began with the words, *"If E is the emission of a black body at the temperature of this layer and one assumes that Kirchhoff's law applies, it follows that the layer will radiate the energy Eadh in every direction"* [102, p. 280 — in Meadows].

Beyond the validity of Kirchhoff's law, these derivations sidestepped the reality that clear convection currents existed

*The second Planckian proof [45] was initially treated in [3, 35, 40, 42].

†As nearly perfect absorbers, carbon particles make for poor reflectors.

on the exterior of the Sun [67, 68]. Remarkably, just a few years after publishing his classic derivation of the law of darkening [103], Milne himself argued that local thermal equilibrium did not apply in the outer layers of the stars [69]. Arthur Eddington also recognized that the laws of emission could not be used to treat the photosphere, *"The argument cannot apply to any part of the star which we can see; for the fact that we see it shows that its radiation is not 'enclosed'"* [9, p. 101]. As such, how could Kirchhoff's law be invoked to explain limb darkening?

To further complicate the situation, any explanation of limb darkening for gaseous models would once again resurrect the solar opacity problem [42]. How could the exterior of the Sun generate a perfect blackbody spectrum using an assembly of processes not seen within graphite?

Gas models accounted for limb darkening by insisting that the observer was sampling different depths within the Sun (see Fig. 5). When viewing the center of the disk, our eye was observing radiation originating further in the interior. This radiation was being released from a layer which was at a higher temperature. Hence, by the Wien's law [17] it appeared brighter. As for limb radiation, it was being produced at shallower depths, thereby appearing cooler and darker.

These ideas were reliant on the belief that the surface of the Sun was merely an illusion,* a conjecture which will be refuted in §3.1, §3.2, §3.7, §4.3, §4.5, §5.1, §5.2, §5.5, §5.7, §6.1, §6.2, and §6.3.

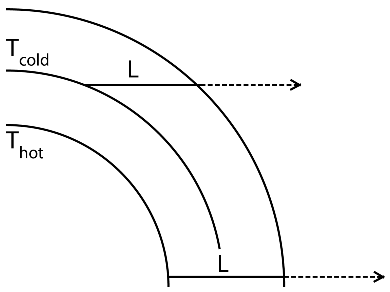

Fig. 5: Schematic representation of how limb darkening is explained in the gas models. When viewing the center of the solar disk, the line of sight travels to a greater depth (L), where it reaches a hotter layer in the solar body. Conversely, when the limb is visualized, the line of sight (L) is restricted to a cooler upper layer. One of the fallacies of this explanation is that the outer layers of the photosphere cannot be considered enclosed (i.e. we can see through them when we visualized the center of the disk). So, photospheric radiation could not be blackbody, even assuming that Kirchhoff's law was valid. Eddington himself had reached this conclusion [9, p. 101].

In the end, the simplest explanation for limb darkening lies in the recognition that directional spectral emissivity occurs naturally within condensed matter [66, 71–73]. Poor conductors tend to have elevated normal emissivities which gradually fall as the angle of observation is decreased (see Fig. 6). This is precisely what is being observed across the solar disk. Good conductors often display lower normal emissivities, which can gradually increase as the angle of observation is decreased, prior to decreasing rapidly as the viewing angle becomes parallel to the surface (see Fig. 6).

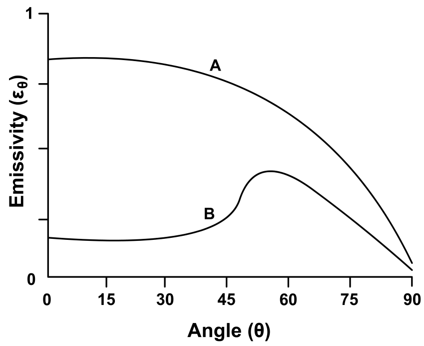

Fig. 6: Schematic representation of directional spectral emissivities for non-conductors (A) and conductors (B). Note that in non-metals, the spectral emissivity decreases monotonically with viewing angle. Conversely, in metals, while the normal emissivity can be substantially reduced, the emissivity can rise with increasing angle before precipitously dropping (adapted from [72]).

Limb darkening revealed that the solar photosphere was condensed, but not highly metallic.† Graphite itself behaves as an excellent emitter, but only a modest conductor. It can be concluded, based on Figs. 4 & 6, that the liquid metallic hydrogen which comprises the solar surface is not highly metallic. The inter-atomic distances in this graphite-like layered material (a Type-I lattice) would be slightly larger than those found in the more metallic sunspots (a Type II lattice), as previously described by the author [35, 39, 40].

2.3.3 Sunspot Emissivity #3

Galileo viewed sunspots (see Fig. 7) as clouds floating very near the solar surface [105].‡ His great detractor, Christoph Scheiner, initially saw them as extrasolar material [2], but eventually became perhaps the first to view them as cavities [1, p. 15, V. I]. This apparent depression of sunspots was confirmed by Alexander Wilson [2] who, in 1774 [106], used precise geometric arguments to establish the effect which now bears his name [1, p. 70–74]. In 1908, George Ellery Hale discovered that sunspots were characterized by intense magnetic fields [107]. This remains one of the most far reaching findings in solar science.

*To this day, astronomy continues to maintain that the Sun's surface is an illusion, as seen in this text produced by the National Solar Observatory, *"The density decreases with distance from the surface until light at last can travel freely and thus gives the illusion of a visible surface"* [104, p. 4].

†As a side note, Frank Very had suggested [101] that the limb darkening of the Sun might be associated with the solar granulations [3, 101]. As will be seen in §2.3.4, the thought was not without merit.

‡The third Planckian proof [45] was initially the 13th line of evidence [35]. It has been presented, in greater detail, within [4, 40, 45].

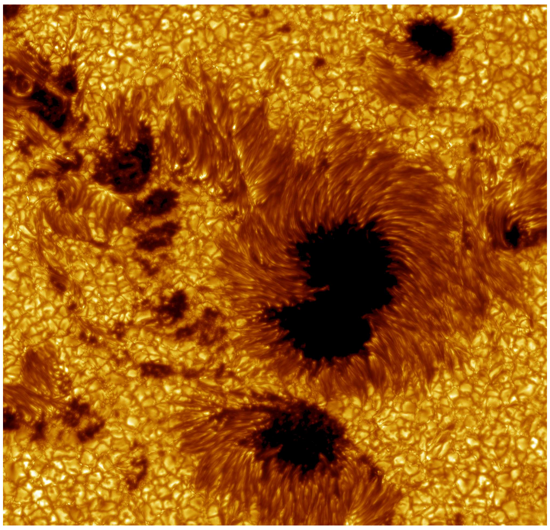

Fig. 7: Part of a sunspot group near the disk center acquired with the Swedish 1-m Solar Telescope [100]. This image has been described as follows by the Institute for Solar Research of the Royal Swedish Academy of Sciences, *"Large field-of-view image of sunspots in Active Region 10030 observed on 15 July 2002. The image has been colored yellow for aesthetic reasons … Dark penumbral cores — Observations: Göran Scharmer, ISP; Image processing: Mats Löfdahl, ISP; Wavelength: 487.7 nm; Target: AR10030; Date: 15 Jul 2002"*. This image is available for publication thanks to the generosity of the Royal Swedish Academy of Sciences (www.solarphysics.kva.se/NatureNov2002/press_images_eng.html — accessed online 9/15/2013). The SST is operated on the island of La Palma by the Institute for Solar Physics of the Royal Swedish Academy of Sciences in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias.

In addition to the Wilson effect, sunspot emissivity has been found to drop significantly with increasing magnetic field strength [108, 109]. The magnetic fields within sunspot umbra are known to have a vertical orientation. Their intensity increases in the darkest regions of the umbra (e.g. [110, p. 75] and [111, p. 80]). Sunspot emissivity has also been hypothesized to be directional, with increasing emissivity towards the limb [111, p. 75–77]. In this regard, Samuel Langley had observed, *"With larger images and an improved instrument, I found that, in a complete ring of the solar surface, the photosphere, still brilliant, gave near the limb absolutely less heat than the umbra of the spots"* [112, p. 748]. Edwin Frost echoed Langley, *"A rather surprising result of these observations was that spots are occasionally relatively warmer than the surrounding photosphere"* [113]. Today, the apparent directional changes in the emissivity of sunspots has been dismissed as due to *'stray light'* [111, p. 75–77].

Since a gaseous Sun is devoid of a real surface, the *'Wilson Effect'* cannot be easily explained within these bounds. Once again, optical depth arguments must be made (e.g. see [110, p. 46] and [114, p. 189-190]). In order to account for the emissivity of sunspots, gaseous models propose that magnetic fields prevent the rising of hot gases from the solar interior [104]. Hence, the spot appears cool. But sunspots can possess light bridges (see Secchi's amazing Fig. 33 in [1, p. 69, V. I]). These are characterized by higher emissivities and lower magnetic fields [111, p. 85–86]. The problem for the gaseous models is that light bridges seem to *'float'* above the sunspot. How could these objects be warmer than the material below? Must a mechanism immediately be found to heat light bridges? Sunspots are filled with substructure, including that which arises from Evershed flow. Such substructure is well visible in Fig. 7. However, gases are unable to support structure. How can a gaseous solar model properly account for Evershed flow, while dismissing the surface as an illusion? The problem, of course, remains that all these illusions actually are behaving in systematic fashion (see §5.1). Furthermore, in modern astronomy, the apparent change in sunspot emissivity towards the limb must be dismissed as a *'stray light'* effect. But the most pressing complication lies in the reality that gases are unable to generate powerful magnetic fields (see §5.3). They can respond to fields, but have no inherent mechanism to produce these phenomena. Along these lines, how can magnetic fields be simultaneously produced by gases while at the same time prevent them from rising into the sunspot umbra? On Earth, the production of powerful magnets involves the use of condensed matter and the flow of electrons within conduction bands, not isolated gaseous ions or atoms (see §5.3).

In contrast to the gaseous models, the idea that the Sun is comprised of condensed matter can address all of these complications. The *'Wilson Effect'*, one of the oldest and simplest of solar observations, can continue to be explained without difficulty by using elementary geometry [106], precisely because a true surface can be invoked [45]. The lowered emissivity of sunspot umbra, in association with increased magnetic field strengths, strongly suggests that sunspots are metallic in nature. Langley's observation that sunspots display increased limb emissivity relative to the photosphere can be explained as related to metallic effects.* The increased emissivity and lower magnetic field strength observed within light bridges could be explained by assuming that they, like the photosphere, are endowed with a Type I lattice [35, 39, 40] with lowered metallic properties. Conversely, the decreased normal emissivity of sunspot umbra along with their increased magnetic field strength suggests a more metallic Type II lattice [35, 39, 40] in these structures.

In sunspots, the electrons responsible for generating magnetic fields can be viewed as flowing freely within the conduction bands available in metallic hydrogen. This implies

*This is not to say that stray light cannot present problems. However, these effects should make faculae even less apparent towards the limb, further highlighting the importance of the increase in emissivity which those structures display (see §2.3.5). Definitive answers may come eventually by examining large sunspots.

that the lattice within sunspot umbrae are positioned so that the hexagonal hydrogen planes (see direction A in Fig. 2) are nearly orthogonal to the solar surface (see Fig. 8). In the penumbra, they would be oriented more horizontally, as demonstrated by the magnetic field lines in this region. The accompanying emissivity would be slightly stronger, resulting in the penumbra appearing brighter. As such, the emissivity in layered metallic hydrogen appears to be highly dependent on the orientation of the hexagonal hydrogen planes.

Likewise, it has been observed that sound waves travel faster within sunspots than within the photosphere [116, 117]. These findings are supportive of the idea that sunspots are denser and more metallic than the photosphere itself. The use of condensed matter brings with it both structure and function.

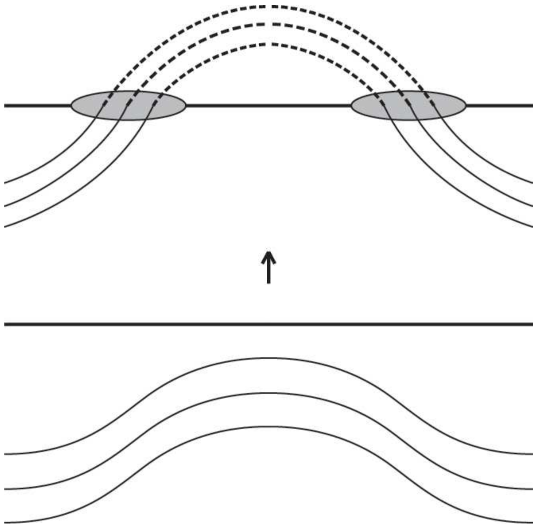

Fig. 8: Schematic representation of the appearance of a pair of sunspots on an active solar surface. The horizontal thick line illustrates the location of the photosphere, the thin lines the layers of metallic hydrogen, and the dashed lines the magnetic field. The two shaded circles outline the position of sunspots. In the lower portion of the figure, the layers of metallic hydrogen are below the level of the photosphere, but are being pushed up by intercalate elements which have entered the gas phase (see §5.1 in [48]). In the upper portion of the figure, the layers of metallic hydrogen have now broken through the photospheric level. The two sunspots are being linked solely by magnetic field lines, as the metallic hydrogen which once contained them has vaporized into the solar atmosphere. This figure is an adaptation based on Fig. 22 in [115]. Along with this legend, it previously appeared in [52].

2.3.4 Granular Emissivity #4

When observed at modest resolution, the surface of the Sun is covered with granules (see Fig. 9).* The appearance of these structures caused considerable controversy within astronomy in the mid-1800s [40], but they have been well described and illustrated [118–122] since the days of Father Secchi [1, p. 48–59, V. I]. Individual granules have limited lifetimes, can be arranged in mesogranules, supergranules, or giant cell [40, 118–122], and seem to represent a convective process.†

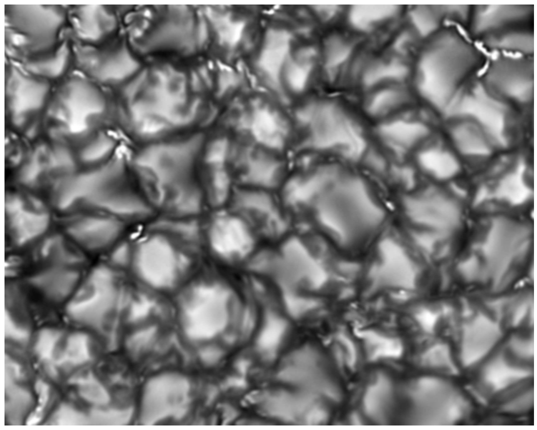

Fig. 9: High resolution image of solar granules acquired by Vasco Henriques on May 23, 2010 using the Swedish 1-m Solar Telescope (SST). Bright granules are surrounded by dark intergranular lanes which can contain magnetic bright points (see §2.3.5). This image has been described as follows, *"The SST is operated on the island of La Palma by the Institute for Solar Physics of the Royal Swedish Academy of Sciences in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias — High resolution granulation — Observer: Vasco Henriques; Image processing: Vasco Henriques Date: 23 May 2010"*. http://www.solarphysics.kva.se (accessed online 9/15/2013).

Though granules are dynamic convective entities which are constantly forming and dying on the surface of the Sun, they have been found to observe the laws of Aboav-Weaire and of Lewis [123–125], along with the perimeter law, for space filling structures in two dimensions [126]. That granules can be viewed as crystals was first hypothesized by Chacornac in 1865 [127]. Clearly, the laws of space filling cannot be applied to gases which expand to fill the space of containers. They cannot, on their own, restrict the spatial extent which they occupy. The laws of space filling can solely be observed by materials which exist in the condensed state. Adherence to these laws by granules [126] constitutes important evidence that these structures are comprised of condensed matter.

Studies reveal that granules can contain *'dark dots'* at their center, linked to *'explosive'* structural decay. Rast [128] has stated that this decay *"can be better understood if granu-*

*The fourth Planckian proof [45] was initially part of the 14th line of evidence [45]. It has been presented, in greater detail, within [40] which contains an extensive list of references on the subject.

†This aspect of solar granules will be discussed in §5.1 as it is linked to activity on the solar surface. For the time being, the focus will remain on the structural and emissive aspects.

lation is viewed as downflow-dominated-surface-driven convection rather than as a collection of more deeply driven upflowing thermal plumes". These arguments depend on the presence of a true solar surface. Noever has linked the decay of granules associated with the appearance of *'dark dots'* to the perimeter law alone [126], once again implying that structure determines dynamic evolution.

Granules are characterized by important emissive characteristics. These structure tend to be brighter at their center and surrounded by dark intergranular lanes (see Fig. 9) whose existence has been recognized by the mid-1800s [40].

In order to account for the emissive properties of granules, the gaseous models maintain that these structures represent convective elements. Hot gases, rising from deep within the Sun, emerge near the center of these formations, while cooler material, held in the dark intergranular lanes, slowly migrates towards the solar interior. In this case, emissivity is linked to temperature changes alone, as dictated by Wien's law [17]. This hypothesis rests on the validity of Kirchhoff's law [15, 16, 20–24] and depends upon subtle changes in solar opacity [42] in adjacent regions of the solar surface. As seen in §2.1 and §2.2, these arguments are invalid.

Within the context of the LMH model [35, 39], granules are viewed as an integral portion of the true undulating surface of the Sun. Their complex radiative properties can be fully explained by considering directional spectral emissivity. As sub-components of the photosphere, the same mechanism invoked to understand limb darkening §2.3.2 can be used to explain granular emissivity.

The normal emissivity of these bubble-like structures remains somewhat elevated. As the viewing angle moves away from the normal,* emissivity progressively drops in accordance with the known behavior of non-metals (see Fig. 6). Intergranular lanes appear dark, not because they are cooler (an unlikely scenario in the same region of the Sun), but rather, because less photons are observed when the surface being visualized becomes increasingly coincident with the direction of emission. In a sense, with respect to thermal emission, each granule constitutes a mini-representation of the macroscopic limb darkening observed across the disk of the Sun (see §2.3.2), an idea first expressed by Very [101].

In the LMH model, granules therefore possess a Type I lattice [35, 39], which is somewhat less metallic than the Type-II lattice found in sunspots. This is revealed by the lack of strong magnetic fields associated with granules and by the slowly decaying center-to-limb variation in directional emissivity observed on the solar surface (see §2.3.2). In a manner analogous to what is observed in sunspots, the emissivity of layered metallic hydrogen would imply that the hexagonal hydrogen planes are oriented parallel to the solar surface at the center of a granules providing higher emissivity, or brighter appearance, in this instance. The orientation should become more vertical in the intergranular lanes, thereby accounting for their darker appearance. The LMH model [35, 39] dispenses with optical depth and variable temperature arguments. It elegantly accounts for solar emission using a single phenomenon (directional spectral emissivity in condensed matter) applicable across the full range of solar observations.

*Normal viewing occurs when the line of sight is perpendicular to the surface.

2.3.5 Facular Emissivity #5

In visible light, faculae are difficult to observe at the center of the solar disk, but often become quite apparent towards the limb.† Father Secchi noted the difficulty of observing faculae at the center of the disk [1, p. 49, V. I] and George Ellery Hale commented on the enhanced emissivity of faculae towards the limb, *"The bright faculae, which rise above the photosphere, are conspicuous when near the edge of the Sun, but practically invisible when they happen to lie near the center of the disk . . . "* [129, p. 85–86]. Solar faculae appear to float on the photosphere itself. The structures have long been associated with sunspots [130]. Wang et al. recently postulated that these objects could result from the conversion of sunspots, wherein the horizontal magnetic field contained within penumbrae makes a transition to a vertical field in faculae [131]. Faculae are known to possess strong magnetic fields [132–134].

The emissivity of faculae as they approach the solar limb [135] cannot be reasonably explained within the context of the gaseous models. The accepted scheme, Spruit's *'hot wall'* [136, 137] model is illustrated in Fig. 10. When the faculae are at the center of the disk, the observer is able to see deeper into the Wilson depression to the flux tube *'floor'* [137, p. 926]. This floor is thought to be at a lower temperature and, according to the laws of blackbody emission [15–20], appears relatively dark. As for the *'walls'* of the flux tube, they are said to sustain elevated temperatures and appear bright when compared to the deeper *'floor'*. As the flux tube moves towards the limb, the observer can no longer observe the *'floor'* and one of the *'hot walls'* becomes increasingly visible. With time, even that *'hot wall'* disappears. This agrees with observation: facular emissivity is initially indistinguishable from that of the photosphere at disk center. It then increases and becomes bright with respect to the rest of the solar surface, as theses objects move towards the limb. Finally, the emissivity decreases precipitously at the limb.

To help explain the emissivity of faculae, the gas models suggest macroscopic structures, *'cool floors'* and *'hot walls'*. Gases are incapable of generating such features. In faculae, flux tubes are said to be permitting heat from the solar interior to rise into the *'hot walls'*. Yet, to account for the darkness

†The fifth Planckian proof, as related to facular emissivity, was initially presented as the 15th line of evidence [45].

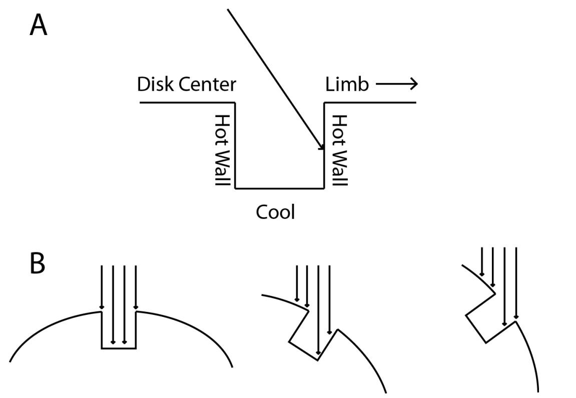

Fig. 10: Schematic representation of Spruit's *'hot wall'* model [136, 137]. A) Faculae are represented as depressions in the solar surface. Depending on the line of sight, the observer will sample either a *'cool floor'*, or a *'hot wall'*. B) When sampling at the center of the solar disk, he/she will only be able to visualize a *'cool floor'* whose temperature approaches that of the granules on the surface. Under the circumstances, the faculae are not visible. However, as these objects move towards the limb, the line of sight will initially sample more of the *'hot wall'* and the faculae appear brighter. When the edge of the Sun is approached, the hot walls can no longer be readily sampled and the emissivity of the faculae are perceived to drop rapidly.

within sunspots, the models had required that field lines inhibited the upward flow of hot gases beneath the umbra (see §2.2.3).

It is immediately apparent that the emissive behavior just described within faculae exactly parallels the known radiative properties of metals, as previously illustrated in Fig. 6. Faculae possess strong magnetic fields [132–134]. In combination with their directional emissivity, this all but confirms that they are metallic in nature.

In addition to faculae, an extension of Spruit's hot wall model has been invoked to explain the presence of magnetic bright points found within the dark intergranular lanes of the granules [138]. As the name implies, magnetic bright points are also believed to possess strong magnetic fields [12, 138, 139]. Moreover, they display powerful center-to-limb variations in their emissivity [138], being most visible at the center of the solar disk within the dark intergranular lanes. In the case of magnetic bright points, it is the *'floor'* which is viewed as bright, as light is said to originate from *"deeper photospheric layers that are usually hotter"* [138].*

The problem rests in the realization that magnetic bright points are located within the dark intergranular lanes. As a result, in order to explain the presence of locally strong magnetic fields within these objects, it is hypothesized that an *"efficient turbulent dynamo transforms into magnetic fields part of the kinetic energy of the granular convection"* [138]. This serves to emphasize the problems faced by the gas models.

Within the context of the LMH model [35, 36, 39], the presence of faculae and magnetic bright points on the solar surface are elegantly explained by invoking lattice structure. Since faculae are associated with sunspots [130] and even thought to be ejected from these structures [131], it is reasonable to propose that they can be metallic in nature (see Fig. 6), that their structural lattice mimics the type II lattice found in sunspots, and that they have not yet relaxed back to the Type-I lattice found in granules. In this case, the brightness of faculae implies that their hexagonal hydrogen planes lie parallel to the solar surface. This should account for both emissivity and the presence of associated magnetic fields in these structures.

In the end, the simplest explanation for the origin for magnetic bright points may be that they are nothing more than facular elements. Rising from internal solar regions, they have not fully relaxed from a Type II to a Type I lattice, but have been transported through granular flow to deeper intergranular lanes. Their center-to-limb emissivity variations may well rest in the realization that they are hidden from view by the granules themselves as the limb is approached. Hence, their numbers appear to fall towards the edge of the solar disk [138].

2.3.6 Chromospheric Emissivity #6

While hydrogen-α emissions are responsible for the red glow of the chromosphere visible during an eclipse, this region of the Sun also emits a weak continuous spectrum [56] which has drawn the attention of solar observers for more than 100 years [140–147].† Relative to this emission, Donald Menzel noted, *"…we assumed that the distribution in the continuous chromospheric spectrum is the same as that of a black body at 5700°, and that the continuous spectrum from the extreme edge is that of a black body at 4700°. There is evidence in favor of a lower temperature at the extreme limb in the observations by Abbot, Fowle, and Aldrich of the darkening towards the limb of the Sun"* [142].

The gaseous models infer that the chromosphere has an average density of $\sim 10^{-12}$ g/cm^3 [115, p. 32].‡ Despite a 10^5 drop in density with respect to the photosphere, these treatments continue to advance that the continuous emission in the chromosphere is being produced by neutral H, H$^-$, Rayleigh scattering, and electron scattering (see [145, 146] and [150, p. 151–157]). But, none of these processes can be found in graphite (see §2.1 and §2.2).

*These layers were not hotter in Spruit's model [136, 137].

†The sixth Plankian proof [45] was initially presented as the 26th line of evidence [56].

‡In these models, the photosphere is assumed to have a density of $\sim 10^{-7}$ g/cm^3, while the outer chromosphere has a density of $\sim 10^{-15}$ g/cm^3 [148]. This constitutes an 8 order of magnitude decrease in just a few thousand kilometers. As a point of reference, the density of the Earth's atmosphere at sea level is $\sim 1.2 \times 10^{-3}$ g/cm^3 [149] or $\sim$10,000 greater than calculated photospheric densities for the gas models.

Alternatively, within the context of the LMH model, the chromospheric continuous emission provides evidence that condensed matter exists in this region of the solar atmosphere [56]. This is in keeping with the understanding that continuous spectra, which can be described using blackbody behavior, must be produced by condensed matter [21–24]. In this regard, the chromosphere may be viewed as a region of hydrogen condensation and recapture within the Sun. Though generating condensed matter, the chromosphere is not comprised of metallic hydrogen.*

2.3.7 K-Coronal Emissivity #7

The white light emitted by the K-corona is readily visualized during solar eclipses.† Observing from Iowa in 1869, William Harkness *"obtained a coronal spectrum that was continuous except for a single bright green line, later known as coronal line K1474"* on the Kirchhoff scale [151, p. 199]. Eventually, it became clear that the continuous spectrum of the K-corona was essentially identical to photospheric emission [152–156], with the important distinction that the former was devoid of Fraunhofer lines. In addition, the spectrum of the K-corona appeared to redden slightly with increasing distance from the solar surface, *"microphotograms for solar distances varying from R=1.2s to R=2.6s show that the coronal radiation reddens slightly as the distance from the Sun is increased"* [156]. The reddening of the K-coronal emission suggested that the corona was cooling with increased distance from the solar surface.‡

Within the context of the gas models, the corona is extremely hot and thus, cannot be self-luminous in the visible spectrum. Rather, these models maintain that coronal white light must represent photospheric radiation. But as the thermal spectrum from the photosphere is punctuated with Fraunhofer absorption lines (see §3.7), some mechanism must be devised to explain their absence in coronal light. As such, proponents of the gaseous models have proposed that coronal light is being scattered by highly relativistic electrons [115, 148, 157, 158]. The Fraunhofer absorption lines are hypothesized to become highly broadened and unobservable. Relativistic electrons require temperatures in the millions of degrees. These temperatures are inferred from the line emissions of highly ionized ions in this region of the Sun (see §3.8). Unfortunately, such a scheme fails to account for the reddening of the coronal spectrum [156].

In contrast, the LMH model [35, 39] states that the solar corona contains photospheric-like condensed matter (Type I) and is, accordingly, *self-luminous* [57]. It is well-known that the Sun expels material into its corona in the form of flares and coronal mass ejections. It is reasonable to conclude that this material continues to emit (see §2.3.8) and may eventually disperse into finely distributed condensed matter in this region of the Sun. The reddening of the coronal spectrum implies that the apparent temperatures of the corona are no greater than those within the photosphere.§ The apparent temperature slowly decreases, as expected, with increased distance from the solar surface. The production of highly ionized ions in the corona reflects condensed matter in the outer solar atmosphere (see §2.3.8, §3.8, and §5.5). As for the Fraunhofer lines, they do not appear on the spectrum of the K-corona owing to insufficient concentrations of absorbing species exist in this region of the Sun. There is no need to invoke scattering by relativistic electrons.

2.3.8 Coronal Structure Emissivity #8

The corona of the active Sun is filled with structures easily observed using white-light coronographs [154, 155].¶ Flares [159–162], prominences and coronal mass ejections [163–171], streamers [172–174], plumes [175], and loops [176–178], can all be visualized in white light.

The mechanism for generating white-light in this wide array of structures remains elusive for the gaseous models, in part because the densities, in which they are hypothesize to exist, are lower than ~10^{-15} g/cm^3 [148]. Moreover, the release of white-light by these structures tends to be explosive in nature, particularly when flares are involved [179–186]. These phenomena cannot be adequately explained by relying on gradual changes in opacity [42] or the action of rela-

*Metallic hydrogen requires extreme pressures for formation [39, 92] which can only exist within the solar body. As a result, though condensation is occurring within the chromosphere and corona, the resulting products are not metallic. Rather, it is likely that chromospheric material is comprised of dense hydrogen wherein molecular interactions between hydrogen atoms still persists [92]. Conversely, condensed matter which has been ejected from the solar body can be metallic in character and has been proposed to become distributed throughout the corona [60]. The solar atmosphere can simultaneously support the existence of two forms of hydrogen: chromospheric non-metallic material, like as coronal rain or spicules (see §5.4, §5.6 and [53, 59]) and coronal material which resembles photospheric Type-I metallic hydrogen (see §2.3.7 and §2.3.8) and [57, 58, 60]) and which can be found in the corona and its associated structures (see §3.8, §4.6, §5.5, §5.7 and §6.6 for complimentary evidence).

†The seventh Plankian proof [45] was initially presented as the 27th line of evidence [57, 60].

‡Yet, the *"single bright green line"* which had been observed by Harkness would eventually be identified as originating from highly ionized iron (i.e. FeXIV). Within the gaseous context, the only means of generating these ions would involve the presence of extreme temperatures in the corona. Conversely, the ions could be produced if condensed matter can be postulated to exist in this region of the Sun. The origin of highly ionized ions in the corona constitutes one of the most elegant lines of evidence for the presence of condensed matter in this region of the Sun, supporting the idea that the corona is, in fact, cool (see [60] and §3.8 for a complete discussion).

§The author has stated that the true energy content of the photosphere would correspond to real temperatures in the millions of degrees. The vast majority of this energy is trapped within the translational degrees of freedom associated with the differential convection currents. The conduction bands responsible for the solar magnetic fields likewise harness some of the solar surface energy. The apparent temperature of ~6,000K corresponds to the energy contained within the photospheric vibrational degrees of freedom [41].

¶The eighth Plankian proof [45] was initially presented as the 28th line of evidence [58].

tivistic electrons to scatter photospheric light [160, 161, 164, 187, 188]. Currently, many of these structures are believed to derive their energy from coronal magnetic sources overlying active regions [12]. That is a result having no other means of accounting for this extensive and abrupt release of energy in the gaseous Sun [179].

Within the context of the LMH model [35, 39], the white-light emitted by coronal structures is associated with their condensed nature. Since many of these formations originate from eruptions taking place at the level of the photosphere, such a postulate appears reasonable. As a result, coronal structures should be regarded as *self-luminous*. The explosive increase in white-light is related to powerful lattice vibrations associated with their formation [21]. Long ago, Zöllner [189] had insisted that flares involved the release of pressurized material from within the Sun [3]. These mechanisms remain the most likely, as they properly transfer energy out of the solar body, not back to the surface from the corona (see §5.1).

3 Spectroscopic Lines of Evidence

Though Gustav Kirchhoff erred [21–24] relative to his law of thermal emission [15, 16], his contributions to solar science remain unchallenged. Not only was he amongst the first to properly recognize that the Sun existed in liquid state [2, 26], but as the father of spectral analysis, along with Robert Bunsen, he gave birth to the entire spectroscopic branch of solar science [190, 191]. Using spectroscopic methods, Kirchhoff successfully identified the lines from sodium on the Sun and this led to an avalanche of related discoveries, spanning more than a century [190, 191]. Indeed, all of the thermal proofs discussed in §2, are the result of spectroscopic analysis, centered on the blackbody spectrum observable in visible and infrared light. It is fitting that the next series of proofs are spectroscopic, this time centering on line emission of individual atoms or ions. These eight lines of evidence highlight anew the power of Kirchhoff's spectroscopic approaches.

3.1 UV/X-ray Line Intensity #9

The Sun is difficult to study in the ultraviolet (UV) and X-ray bands due to the absorption of this light by the Earth's atmosphere.[*] As a consequence, instruments like the AIA aboard NASA's Solar Dynamic Observatory (see Fig. 11) are being used for these observations [192, p. ix]. When the Sun is observed at these frequencies, striking evidence is produced on the existence of a real solar surface. Harold Zirin describes the findings as follows, "*The case in the UV is different, because the spectrum lines are optically thin. Therefore one would expect limb brightening even in the absence of temperature increase, simply due to the secant increase of path length. Although the intensity doubles at the limb, where we see the back side, the limb brightening inside the limb is minimal . . . Similarly, X-ray images show limb brightening simply due to increased path length.*" [193]. Fig. 11 presents this phenomenon in X-Ray at 94Å, for a somewhat active Sun.[†]

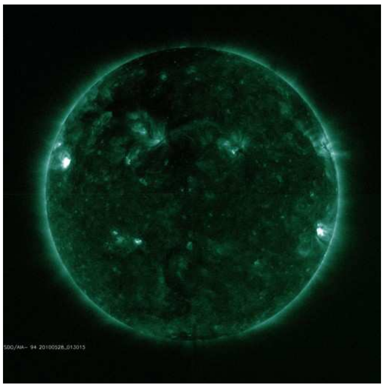

Fig. 11: AIA X-Ray image of an active Sun obtained on 5/28/2010 at 94Å displaying limb brightening and surface activity. This image (20100528_013015_512_0094.jpg) has been provided Courtesy of NASA/SDO and the AIA, EVE, and HMI science teams using data retrieval (http://sdo.gsfc.nasa.gov/data/aiahmi).

When the observer is directly examining the center of the opaque solar disk, weak spectral lines are obtained at these frequencies. The lines brighten slightly as observation moves towards the limb, owing to a slightly larger fraction of the solar atmosphere being sampled (line of sight 2 versus 1 in Fig. 12). However, immediately upon crossing the solar limb, a pronounced increase in spectroscopic intensity can be recorded. In fact, it approximately doubles, because a nearly two-fold greater line of sight is being viewed in the solar atmosphere. This can be understood if one would compare a line of sight very near line 3 in Fig. 12 (but still striking the solar disk) with line 3 itself.

In this manner, UV and X-ray line intensities can provide strong evidence that the Sun possesses an opaque surface at these frequencies which is independent of viewing angle. Limb darkening is not observed, as was manifested in the visible spectrum (see §2.3.2), in that condensed matter is not being sampled. Rather, the behavior reflects that gases are being monitored above a distinct surface through which UV and X-ray photons cannot penetrate.[‡]

3.2 Gamma-Ray Emission #10

Occasionally, powerful gamma-ray flares are visible on the surface of the Sun and Rieger [194] has provided evidence that those with emissions >10 MeV are primarily visualized

[*] This proof was first presented as the 25th line of evidence [55].

[†] A 171Å UV image from the quite Sun has been published [192, p. 38]. The Solar Dynamic Observatory website can be accessed for images at other frequencies in the ultra-violet (http://sdo.gsfc.nasa.gov/data/aiahmi).

[‡] Note that these findings further bring into question the optical depth arguments that had been brought forth to explain limb darkening within the gaseous models in §2.3.3. Should the Sun truly possess a vacuum-like photospheric density of only 10^{-7} g/cm^3 [148], then the limb should not act as such a dramatic boundary relative to the intensity of UV and X-ray emissions.

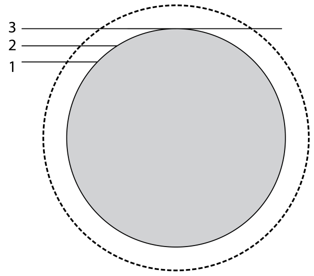

Fig. 12: Schematic representation of path lengths present when the outer atmosphere (area outlined by dashes) of the Sun (body in gray) is viewed from the Earth. Paths 1 and 2 terminate on the solar surface. Just beyond the limb, path 3 samples the front and back side of the solar atmosphere, resulting in a two fold increase in line intensity. This figure is an adaptation based on Fig. 2.4 in [192] and, along with this legend, was previously published [55].

near the solar limb (see Fig. 13).* Speaking of Rieger's findings, Ramaty and Simnett noted that "*Gamma-ray emitting flares are observed from sites located predominantly near the limb of the Sun . . . This effect was observed for flares detected at energies >0.3 MeV, but it is at energies >10 MeV that the effect is particularly pronounced . . . Since in both of these cases the bulk of the emission is bremsstrahlung from primary electrons, these results imply that the radiating electrons* (are) *strongly anisotropic, with more emission in the directions tangential to the photosphere than in directions away from the Sun*" [195, p. 237].

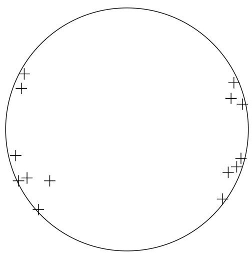

Fig. 13: Schematic representation of approximate flare positions with >10 MeV of energy on the solar disk displaying their predominance near the limb. This figure is meant only for illustrative purposes and is an adaptation based on Fig. 9 in [194] which should be examined for exact flare locations. This figure was previously published in [49].

The production of anisotropic emission would typically imply that structural constraints are involved in flare production. Since the gaseous Sun cannot sustain structure, another means must be used to generate this anisotropy. Based on theoretical arguments, Ramaty and Simnett consequently advance that: "*. . . the anisotropy could result from the mirroring of the charged particles in the convergent chromospheric magnetic fields*" [195, p. 237]. The anisotropy of gamma-ray emission from high energy solar flares is thought to be generated by electron transport in the coronal region and magnetic mirroring of converging magnetic flux tubes beneath the transition region [195]. The energy required for flare generation could thereby be channeled down towards the solar surface from the corona itself. Conveniently, the chromosphere instantly behaves as an *'electron mirror'*. Devoid of a real surface, another mechanism was created to *act* as a surface.

The inability to generate flare anisotropy using the most obvious means — the presence of a true photospheric surface — has resulted in a convoluted viewpoint. Rather than obtain the energy to drive the flare from within the solar body, the gaseous models must extract it from the solar atmosphere and channel it down towards the surface using an unlikely mechanism. It remains simpler to postulate that the anisotropy observed in high energy solar flares is a manifestation that the Sun has a true surface. The energy involved in flare generation can thereby arise from the solar interior, as postulated long ago by Zöllner [189]. In this respect, the LMH model [35, 39] retains distinct advantages when compared to the gaseous models of the Sun.

3.3 Lithium Abundances #11

Kirchhoff's spectroscopic approaches [190,191] have enabled astronomers to estimate the concentrations of many elements in the solar atmosphere.† Application of these methods have led to the realization that lithium was approximately 140-fold less abundant in the solar atmosphere than in meteors [196, 197].

In order to explain this discrepancy, proponents of the gaseous stars have advanced that lithium must be transported deep within the interior of the Sun where temperatures $>2.6\times10^6$ K are sufficient to destroy the element by converting it into helium [^{7}Li $(p,\alpha)^4$He] [198]. To help achieve this goal, lithium must be constantly mixed [198–200] into the solar interior, a process recently believed to be facilitated by orbiting planets [201, 202]. Though these ideas have been refuted [203], they highlight the difficulty presented by lithium abundances in the gaseous models.

As for the condensed model of the Sun [35, 39], it benefits from a proposal [54], brought forth by Eva Zurek, Neil Ashcroft, and others [204], that lithium can act to stabilize metallic hydrogen [88, 92]. Hence, lithium levels could appear to be decreased on the solar surface, as a metallic hydrogen Sun retains the element in its interior. At the same time, lithium might be coordinated by metallic hydrogen in the corona, therefore becoming sequestered and unavailable for emission as an isolated atom.

*This proof was first presented as the eighteenth line of evidence [49].

†This proof was initially discussed in [54]. See [47], for a detailed discussion of how elemental abundances have been estimated.

In this manner, lithium might be unlike the other elements, as these, including helium, are likely to be expelled from the solar interior (see §5.1) as a result of exfoliative forces [48]. Lithium appears to have a low abundance, but, in reality, it is not being destroyed. This would better reconcile the abundances of lithium observed in the solar atmosphere with that present in extrasolar objects. Clearly, if lithium is being destroyed within the stars, it becomes difficult to explain its abundance in meteors. This problem does not arise when abundances are explained using a LMH model, as metallic hydrogen can sequester lithium into its lattice.

3.4 Hydrogen Emission #12

The *'flash spectrum'* associated with solar eclipses characterizes the chromosphere.* The strongest features within this spectrum correspond to line emissions originating from excited hydrogen atoms. As far back as 1931, the outstanding chromospheric observer, Donald H. Menzel, listed more than twenty-three hydrogen emission lines originating from this region of the Sun (see Table 3 in [205, p. 28]). It is the cause of these emissions which must now be elucidated. The most likely scenario takes advantage of the condensation appearing to occur in the chromospheric layer (see §5.4 §5.6 and [56, 59]).

By modern standards, the nature of the chromosphere remains a mystery, as Harold Zirin reminds us, *"The chromosphere is the least-well understood layer of the Sun's atmosphere...Part of the problem is that it is so dynamic and transient. At this height an ill-defined magnetic field dominates the gas and determines the structure. Since we do not know the physical mechanisms, it is impossible to produce a realistic model. Since most of the models ignored much of the data, they generally contradict the observational data. Typical models ignore other constraints and just match only the XUV data; this is not enough for a unique solution. It reminds one of the discovery of the sunspot cycle. While most of the great 18th century astronomers agreed that the sunspot occurrence was random, only Schwabe, an amateur, took the trouble to track the number of sunspots, thereby discovering the 11-year cycle"* [193]. But if mystery remains, it is resultant of the denial that condensed matter exists in this layer of the Sun.

The chromosphere is characterized by numerous structural features, the most important of which are spicules (see Fig. 14) [59, 150]. Even in the mid-1800s, Secchi would provide outstanding illustrations of these objects (see Plate A in [1, V. II]). He would discuss their great variability in both size and orientation, *"In general, the chromosphere is poorly terminated and its external surface is garnished with fringes . . . It is almost always covered with little nets terminated in a point and entirely similar to hair . . . it often happens, especially in the region of sunspots, that the chromosphere presents an aspect of a very active network whose surface, unequal and rough, seems composed of brilliant clouds analogous to our cumulus; the disposition of which resembles the beads of our rosary; a few of which dilate in order to form little diffuse elevations on the sides"* [1, p. 31–36, V. II].

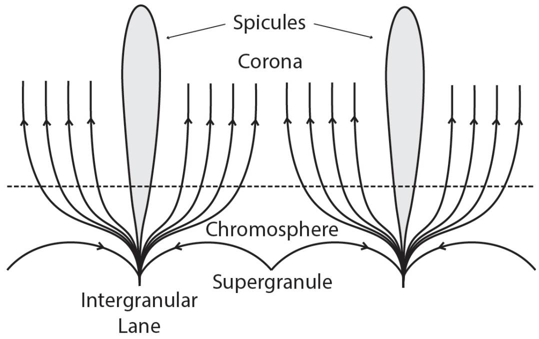

Fig. 14: Schematic representation of spicules overlying the intergranular lane on the outer boundary of a supergranule and surrounded by magnetic field lines emanating from the solar surface. While simplistic, this illustration conveys the basic structural elements needed for discussion. This figure was previously published in [59] and is an adaptation based on Fig. IV-13 in [206, p. 162].

At first glance, spicules are thought to have a magnetic origin, as these fields seem to flood the chromosphere [148, 150, 206–215]. In reality, matter within the chromosphere seems to form and dissipate quickly and over large spatial extent, with spicules reaching well into the corona [148, 150, 206–215]. The random orientation which spicules display, as noted long ago by Secchi [1, p. 31–36, V. II], along with their velocity profiles (see §5.6), should have dispelled the belief that these structures are magnetic in origin. Rather, they appear to be products of condensation (§5.6).†

If spicules and chromospheric matter are genuinely the product of condensation reactions, then their mechanism of formation might shed great light into the emissive nature of this solar layer.

3.4.1 The Liquid Metallic Hydrogen Solar Model

The search for answers begins by considering condensation processes known to occur on Earth [59].

In this respect, while studying the agglomeration of silver clusters, Gerhart Ertl's (Nobel Prize, Chemistry, 2007) laboratory noted that *"Exothermic chemical reactions may be accompanied by chemiluminescence. In these reactions, the released energy is not adiabatically damped into the heat bath of the surrounding medium but rather is stored in an ex-*

*This proof was first presented as the seventeenth line of evidence [47, 59].

†While non-magnetic, spicules might nonetheless be confined by magnetic fields present in the charged plasmas or coronal metallic hydrogen that surrounds them, much as illustrated in Fig. 14.

cited state of the product; decay from this excited state to the ground state is associated with light emission" [216].

The reactions of interest are seldom studied. Those which must arouse attention involve the condensation of two silver fragments and the formation of an activated cluster species: $Ag_n + Ag_m \rightarrow Ag^*_{m+n}$ [216]. With respect to the chromosphere, the important features of these reactions involve the realization that condensation processes are exothermic.

When silver clusters condense, energy must be dissipated through light emission. This constitutes a vital clue in explaining why the chromosphere is rich in hydrogen emission lines [59, 205]. Once an activated cluster is formed, it can relax by ejecting an excited atom: $Ag^*_{m+n} \rightarrow Ag_{m+n-1} + Ag^*$. The reactions are completed when the ejected excited species emits light to reenter the ground state: $Ag^* \rightarrow Ag + h\nu$.

Taking guidance from the work in metal clusters [216], hydrogen emission lines in the chromosphere might be seen as produced through the condensation of hydrogen fragments, $H_n + H_m \rightarrow H^*_{m+n}$. The resultant condensation product could then relax through the ejection of an excited hydrogen atom, $H^*_{m+n} \rightarrow H_{m+n-1} + H^*$, which finally returns to a lower energy state with light emission, $H^* \rightarrow H + h\nu$. This could give rise to all the Lyman lines ($N_2 > 1 \rightarrow N_1 = 1$). If one postulates that the excited hydrogen atom can hold its electron in any excited orbital $N_2 > 2$, H^{**}, then the remaining complement of hydrogen emission lines could be produced $H^{**} \rightarrow H^* + h\nu$ (Balmer $N_2 > 2 \rightarrow N_1 = 2$, Paschen series $N_2 > 3 \rightarrow N_1 = 3$, and Brackett series $N_2 > 4 \rightarrow N_1 = 4$).

But since the chromosphere is known to possess spicules and mottles [148, 150, 206–215], it is more likely that hydrogen is condensing, not onto a small cluster, but rather, onto very large condensed hydrogen structures, CHS [59].* The most logical depositing species in these reactions would be molecular hydrogen, as it has been directly observed in sunspots [217, 218], on the limb [219], and in flares [218]. Importantly, the emission from molecular hydrogen is particularly strong in chromospheric plages [220], providing further evidence that the species might be the most appropriate to consider.

As a result, it is reasonable to postulate that molecular hydrogen could directly interact with large condensed hydrogen structures, CHS, in the chromosphere [59]. The reaction involved would be as follows: $CHS + H_2 \rightarrow CHS\text{–}H^*_2$. This would lead to the addition of one hydrogen at a time to large condensed structures and subsequent line emission from the ejected excited species, $H^* \rightarrow H + h\nu$. Numerous reactions could simultaneously occur, giving rise to the rapid growth of chromospheric structures, accompanied with significant light emission in all spectral series (i.e. Lyman, Balmer, Paschen, and Brackett).

*Chromospheric condensed hydrogen structures, CHS, are likely to be composed of extremely dense condensed matter wherein molecular hydrogen interactions linger [92].

3.4.2 The Gaseous Solar Models

The situation being promoted in §3.4.1, concerning hydrogen line emission in the chromosphere, is completely unlike that currently postulated to exist within the gaseous Sun [59]. In the gas models, line emission relies on the accidental excitation of hydrogen through bombardment with either photons or electrons [206, p. 2]. The process has no purpose or reason. Atoms are randomly excited, and then, they randomly emit.

Przybilla and Butler have studied the production of hydrogen emission lines and the associated lineshapes in the gaseous models. They reached the conclusion that some of the hydrogen emission lines *"collisionally couple tightly to the continuum"* [221]. Their key source of opacity rests with the H^- ion, which has previously been demonstrated to be incapable of providing the desired continuous emission [42]. Of course, it is impossible to *"collisionally couple tightly to the continuum"* [221] in the gaseous models, as the continuum originates solely from opacity changes produced by an array of processes [42]. In the chromosphere, where average densities are postulated to be extremely low ($\sim 10^{-15}$ g/cm^3 [148]), continuous emission is thought to be produced by neutral H, H^-, Rayleigh scattering, and electron scattering (see [145, 146] and [150, p. 151–157]). Clearly, it is not possible to tightly couple to all of these mechanisms at once.

Przybilla's and Butler's computations [221] involve consideration of line blocking mechanisms and associated opacity distribution functions [222]. Stark line broadening mechanisms must additionally be invoked [223].

Beyond the inability of gases to account for the continuous spectrum and the shortcomings of solar opacity calculations [42], the central problem faced in trying to explain hydrogen emission and the associated line shapes rests in the Stark mechanisms themselves. Stark line broadening relies upon the generation of local electric fields near the emitting hydrogen atom. These fields are believed to be produced by ions or electrons which come into short term contact with the emitting species [223]. On the surface at least, the approach seems reasonable, but in the end, it relies on far too many parameters to be useful in understanding the Sun.

In the laboratory, Stark broadening studies usually center upon *extremely dense plasmas*, with electron numbers approaching 10^{17} cm^{-3} [224]. Stehlé, one of the world's preeminent scientists relative to Stark linewidth calculations [223, 225, 226], has analyzed lineshapes to infer electron numbers ranging from 10^{10} to 10^{17} cm^{-3} [227].† She initially assumes that plasmas existing within the chromosphere (T=10,000 K) have electron numbers in the 10^{13} cm^{-3} range [223]. Other

†While the vast majority of plasma studies report electron densities in the 10^{17} cm^{-3} range, the He I studies range from 10^{15} cm^{-3} to 10^{17} cm^{-3} [224]. The lowest electron numbers, 10^{15} cm^{-3}, are produced using arc discharge low density plasma settings. However, these could have little relevance in the Sun, as arc experiments rely on the capacitive discharge of large voltages. They do not depend on fluctuating electromagnetic fields [228].

sources call for much lower values. For instance, electron numbers of $\sim 10^{16}$ m^{-3} (or $\sim 10^{10}$ cm^{-3}) are obtained from radio measurements by Cairns et al. [229] and of no more than $\sim 10^{15}$ m^{-3} (or $\sim 10^{9}$ cm^{-3}) are illustrated in Dwivedi Fig. 3 [157, p. 285]. Stark experiments on Earth typically utilize electron numbers which are approximately 1–100 million times greater than anything thought to exist in the chromosphere.

A minor objection to the use of Stark broadening to explain the width of the hydrogen lines in the gaseous models rests on the fact that the appropriate experiments on hydrogen plasma do not exist. The plasma form of hydrogen (H II) is made of protons in a sea of electrons. It lacks the valence electron required for line emission. The closest analogue to excited hydrogen in the Sun would be ionized helium in the laboratory [224], although ionized Argon has been used for the Hβ profile [227].*

However, the most serious problem rests in the realization that these methods are fundamentally based on the presence of electric or electromagnetic fields in the laboratory. For instance, the inductively produced plasmas analyzed by Stehlé [227] utilize discharges on the order of 5.8 kV [227]. Inductively produced plasmas involve directionally-oscillating electromagnetic fields. Spark or arc experiments utilize static electric fields to induce capacitive discharges across charged plates. In every case, the applied electric field has *a distinct orientation*. Such conditions are difficult to visualize in a gaseous Sun, particularly within the spicules (see §3.4 and §5.7), given their arbitrary orientations. Random field orientations are incapable of line broadening, as well understood in liquid state nuclear magnetic resonance.

Stark broadening requires constraints on the electric field. In the gaseous models, these must take the form of a charged particle which approaches, precisely at the correct moment, an emitting species. The use of such mechanisms to account for chromospheric line profiles is far from justified. But, as the gaseous models cannot propose another explanation, everything must rest on Stark mechanisms, however unlikely these are to be valid in this setting.

In the end, it is not reasonable that matter existing at the concentration of an incredible vacuum ($\sim 10^{-15}$ g/cm^3 [148]) could be Stark broadened, given the extremely low electron numbers associated with the chromosphere [157, 229]. Computations have merely extended our *'observational range'* to electron numbers never sampled in the laboratory. According to the gas models, the chromosphere is a region of extremely low density, but high density plasmas must be studied to enable Stark analysis. Then, while the results of Stark broadening calculations appear rigorous on the surface, they contain experimental shortcomings. Spatially aligned electric fields cannot exist throughout the spicular region of a fully gaseous solar atmosphere, lone electrons are unlikely to produce the desired electric fields, and atoms such as argon have little relevance to hydrogen. In any case, given enough computational flexibility, any lineshape can be obtained, but opacity considerations remain [42].

*The use of argon to represent hydrogen immediately suggests that these methods are not relevant to the Sun. Unlike hydrogen, argon has valence shells containing up to 18 electrons. This many electrons, when either ionized or polarized, presents an analogue with little or no resemblance to hydrogen and its lone electron.

3.4.3 Summary

As just mentioned in §3.4.2, Stark experiments involve electron densities far in excess of anything applicable to the solar chromosphere. Using the same reasoning, it could be argued that metallic hydrogen has not been created on Earth [39, 92]. The criticism would be justified, but this may be simply a matter of time. Astrophysics has already adopted these materials in other settings [93–96] and experimentalists are getting ever closer to synthesizing metallic hydrogen [39, 92]. The Sun itself appears to be making an excellent case that it is comprised of condensed matter.

Unlike the situation in the gaseous solar models, where hydrogen emission becomes the illogical result of random reactions, within the context of the liquid hydrogen model, it can be viewed as the byproduct of systematic and organized processes (see §3.4.1). An underlying cause is associated with line emission, dissipation of the energy liberated during condensation reactions. The driving force is the recapture of hydrogen through condensation, leading ultimately to its re-entry into the solar interior. This tremendous advantage cannot be claimed by the gaseous models.

Pressure (or collisional) broadening can be viewed as the most common mechanism to explain line broadening in spectroscopy. This mechanism can be invoked in the condensed model, because the atmosphere therein is not devoid of matter (see §2.3.6, §5.4, §5.5, §5.6, §6.6 and [56, 58, 59]).

It is possible that line broadening is occurring due to direct interaction between the emitting species and condensed hydrogen structures in the chromosphere. In this case, emission would be occurring simultaneously with the ejection of hydrogen. Under the circumstances, hydrogen line shapes may be providing important clues with respect to the interaction between molecular hydrogen and larger condensed structures in the chromosphere. If Stark broadening mechanisms play any role in the Sun, it will only be in the context of condensed matter generating the associated electric field.

3.5 Elemental Emission #13

Beyond hydrogen, the solar chromosphere is the site of emission for many other species, particularly the metals of the main group and transition elements.† For gaseous models, these emissions continue to be viewed as the product of random events (see §3.4.2). However, for the LMH model, con-

†This proof was first presented as the thirtieth line of evidence [59].

densation remains the focus (§3.4.1), but this time with the assistance of the hydrides.

The solar disk and the sunspots are rich in hydrides including CaH, MgH, CH, OH, H_2O, NH, SH, SiH, AlH, CoH, CuH, and NiH [230, 231]. CaH and MgH have been known to exist in the Sun for more than 100 years [232]. Hydrogen appears to have a great disposition to form hydrides and this is important for understanding the role which they play in the chromosphere.

At the same time, the emission lines from CaII and MgII are particularly strong in the chromosphere [206, p. 361-369]. These represent emissions from the Ca^+ and Mg^+ ions. Yet, the inert gas configurations for these atoms would lead one to believe that the Ca^{+2} (CaIII) and Mg^{+2} (MgIII) lines should have been most intense in the chromosphere. As such, why is the Sun amplifying the CaII and MgII lines? Surely, this cannot be a random phenomenon (§3.4.2),* as these should have led to the buildup of the most stable electronic configuration.

The answer may well lie in reconsidering the condensation reactions presented in §3.4.1, but this time substituting CaH for molecular hydrogen. It should be possible for CaH and a condensed hydrogen structure, CHS, to interact, thereby forming an activated complex, CHS + CaH → CHS-HCa*. This complex could then emit a CaII ion in activated state, Ca^{+*}, and capture the hydrogen atom: CHS–HCa* → CHS–H + Ca^{+*}. Finally, the emission lines from CaII would be produced, as Ca^{+*} (CaII*) returns to the ground state: $Ca^{+*} \rightarrow Ca^+ + h\nu$. As was the case when discussing the condensation of molecular hydrogen (§3.4.1), if one permits the electrons within the excited state of CaII to initially occupy any electronic orbital, CaII**, then all possible emission lines from CaII could be produced: $Ca^{+**} \rightarrow Ca^{+*} + h\nu$. A similar scheme could be proposed for MgH and the other metal hydrides, depending on their relative affinity for CHS.

There is an important distinction between this scenario and that observed with molecular hydrogen (§3.4.1). When metal hydrides are utilized in this scheme, the condensation reactions are delivering both a proton and *two* electrons to the condensed hydrogen structure. The reactions involving molecular hydrogen delivered a single electron. This interesting difference can help to explain the varying vertical extent of the chromosphere when viewed in Hα, CaII, or HeII (see §3.6 and §4.7).

When sampling the solar atmosphere, electron densities appear to rise substantially as one approaches the photosphere (see [229] and [157, p. 285]). Hence, the lower chromosphere is somewhat electron rich with respect to the upper regions of this layer. Thus, in the lower chromosphere, condensation reactions involving the ejection of atomic hydrogen and neutral atoms can abound. As the altitude increases, a greater affinity for electrons arises and condensation can now be facilitated by species like as the metal hydrides, which can deliver two electrons per hydrogen atom.† This explains why CaII lines in the chromosphere can be observed to rise to great heights [193].

At the same time, lines from neutral metals, M, are more prevalent in the lower chromosphere [193]. Since this area is electron rich, a two electron delivery system is unnecessary and reactions of the following form can readily occur: 1) MH + CHS → CHS-HM*, 2) CHS–HM* → CHS–H + M*, and 3) M* → M + $h\nu$. In this case, only a single electron has been transferred during hydrogen condensation.

Perhaps, it is through the examination of linewidths that the most interesting conclusions can be reached. The emission lines of Hα, Ca, and Mg from spicules are very broad, suggesting a strong interaction between CHS and the ejected atoms, in association with ejection and light emission [234–236]. In contrast, spicule emission linewidths from Hβ, Hγ, Hϵ, the D3 line from He, and the neutral line from oxygen are all sharp [234]. One could surmise that the interaction between these species and condensed hydrogen structures are weaker upon ejection.

It is reasonable to conclude that the hydrides play an important role in facilitating condensation within the chromosphere [59]. Hydrides enable the delivery of hydrogen in a systematic manner and, most importantly, either one or two electrons, depending on the electron densities present on the local level. Such an elegant mechanism to account for the prevalence of CaII and MgII in the chromosphere cannot be achieved by other models. Moreover, unlike the LMH model, the gaseous models take no advantage of the chemical species known to exist in the solar atmosphere.

3.6 Helium Emission #14

The analysis of helium emission in the chromosphere may well provide the most fascinating adventure with regard to the spectroscopic lines of evidence.‡ This stands as fitting tribute to helium [47], as it was first observed to exist on the Sun [237, 238]. These seminal discoveries exploited the presence of helium within prominences and the disturbed chromosphere [239, 240]. Astronomers would come to view solar helium as extremely abundant [241, 242], but these con-

Here is a brief list of interesting ions and the ionization energies required for their production: HII = 13.6 eV; HeII = 24.6 eV; HeIII = 54.4 eV; MgII = 7.6 eV; MgIII = 15.0 eV; CaII = 6.1 eV; CaIII = 11.8 eV and FeXIV = 361 eV [233]. In this respect, note how the first ionized form of helium, HeII, requires 24.6 eV for its production. The generation of many triplet forms of orthohelium HeI will demand energies of ∼20 eV. To remove two electrons from calcium yielding CaIII (the stable Ca^{+2} ion) only requires 11.8 eV. As a result, how can the gas models account for the presence of CaII lines at high altitude on the Sun (5-10,000 km), when this ion only requires 6.1 eV for production? If such powerful HeII and HeI* can be observed, why is CaIII, which requires only 11.8 eV for its generation and has the inert gas, [Ar], configuration, not the preferred form of calcium? This provides a powerful clue that the presence (or absence) of an individual ion on the Sun is related to chemistry and not to temperature.

†As will be seen in §3.8, it is envisioned that the corona of the Sun is harvesting electrons.

‡This proof was first presented as the 32nd line of evidence [61].

clusions have been challenged and may need to be revisited [47, 48, 61]. There is considerable reason to conclude that the solar body is actively ejecting He from its interior [47, 48].

Though helium can be found in spicules [193] and prominences, it is difficult to observe on the solar disk. It can be readily visualized in the chromosphere where the spatial extent of the 30.4 nm HeII emission lines can greatly exceed those from Hα (see the wonderful Fig. 1 in [243]). With increased solar activity, helium emission can become pronounced in the solar atmosphere (see Fig. 15 and [244]).

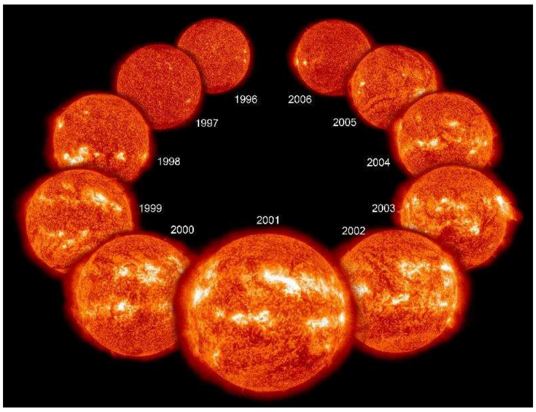

Fig. 15: Image of consecutive years in the solar cycle taken in the HeII line at 30.4 nm. NASA describes this image as follows, *"An EIT image in the 304 Angstrom wavelength of extreme UV light from each year of nearly an entire solar cycle"*. Courtesy of SOHO/[EIT] consortium. SOHO is a project of international cooperation between ESA and NASA. (http://sohowww.nascom.nasa.gov/gallery/images/cycle002.html — Accessed on 9/20/2013).

In the chromosphere, the helium which gives rise to emission lines can possess both of its electrons (HeI) or lose an electron to produce an ion (HeII). HeII resembles the hydrogen atom in its electronic configuration. However, the situation concerning HeI can be more complex. When this species exists in the ground state, both of its electrons lie in the 1S orbital (N=1) with their spins antiparallel, as dictated by Pauli's exclusion principle. In the excited state (i.e. 1 electron in the N=1 shell, and the second electron in any of the N>1 shells), helium can exist either as a singlet (parahelium — spins remaining antiparallel to one another) or as a triplet (orthohelium — spins assume a parallel configuration). Interestingly, the line emissions from the triplet states of orthohelium can be quite strong on the limb of the Sun.

For instance, a well-known triplet HeI transition occurs at 1083 nm (10830Å) which is barely visible on the disk, but it is nearly as intense as Hα on the limb [245, p. 199–200]. At the same time, the HeI triplet D3 line at 588 nm can be enhanced 20 fold when visualization moves from the disk to the limb [245, p. 199-200].*

During the eclipse of March 29, 2006, the triplet D3 line was carefully examined. It appeared to have a binodal altitude distribution with a small maximum at ~250 km and a stronger maximum between 1300-1800 km (see Fig. 6 in [244]). This bimodal distribution was not always observed (see Fig. 7 in [244]). But generally, the D3 line is most intense at an altitude of ~2,000 km, with an emission width of approximately 1,600 km. The triplet D3 lines show no emission near the photosphere.

Within the context of gaseous models, it is extremely difficult to account for the presence of excited HeI triplet states in the chromosphere. Helium requires ~20 eV† to raise an electron from the N=1 shell to the N=2 shell. How can excitation temperatures in excess of 200,000 K be associated with a chromosphere displaying apparent temperatures of 5,000-10,000K, values not much greater than those existing on the photosphere?

Therefore, since proponents of gaseous models are unable to easily account for the powerful D3 line emission, they have no choice but to state that helium is being excited by coronal radiation which has descended into the chromosphere [244, 246]. In a sense, helium must be *'selectively heated'* by the corona. These proposals strongly suggest that the gaseous models are inadequate. It is not reasonable to advance that an element can be selectively excited by coronal radiation, and this over its many triplet states. At the extreme, these schemes would imply that coronal photons could strip away all electrons from chromospheric atoms. Yet, even lines from neutral atoms are observed.‡

On the other hand, helium emissions can be easily understood in the LMH model [35, 36, 39], if attention is turned toward condensation reactions believed to occur within the chromosphere (see §3.4, §3.5 and [59, 61]).

In this respect, it must be recognized that the famous helium hydride cation (HeH^+) *"is ubiquitous in discharges containing hydrogen and helium"* [247].

First discovered in 1925 [248], HeH^+ has been extensively studied [249, 250] and thought to play a key role in certain astrophysical settings [251–253]. In the laboratory, its spectral lines were first observed by Wolfgang Ketterle (Nobel Prize, Physics, 2001) [254, 255]. The author has previously noted, *"Although it exists only in the gas phase, its Brønsted acidity should be extremely powerful. As a result, the hydrogen hydride cation should have a strong tendency to donate a proton, without the concerted transfer of an electron"* [61].

Turning to Fig. 16, it appears that the action of the helium hydride cation, HeH^+, can lead to a wide array of reactions within the chromosphere. These processes are initiated with

*Lines from neutral helium can be enhanced 50 fold on the limb relative to the disk [245, p. 199-200].

†1 eV = 11,600 K ; 20 eV = 232,000 K.

‡Selective excitation was also used to account for the emission lines from molecular hydrogen [220]. But it is more likely that these reflect the delivery of a hydrogen cluster (see §3.4.1) with H_2^* rather than H^* expulsion.

its transfer to condensed hydrogen structures, CHS, believed to be be forming (see §2.3.6, §3.4, §3.5, §3.7, §5.4, §5.6, §6.6) in this region of the solar atmosphere. As was the case with hydrogen (§3.4) and elemental (§3.5) emission lines, everything hinges on the careful consideration of condensation.

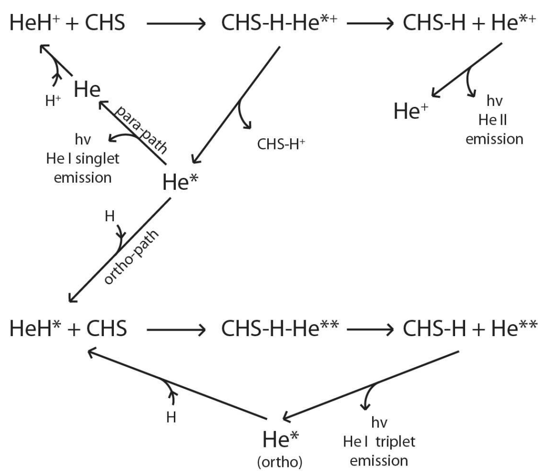

Fig. 16: Schematic representation of possible pathways involved when the helium hydride ion, HeH^+, or the excited helium hydride molecule, HeH^*, react with condensed hydrogen structures, CHS, in the chromosphere of the Sun. The pathways presented can account for all emission lines observed from He I and He II. Note in this scheme that excited helium, He^*, is being produced initially through the interaction of HeH^+ with CHS. This excited helium, He^*, if it assumes the triplet state (orthohelium — electrons in the same orientation: spin up/up or down/down), will become trapped in excited state. This triplet helium can then be used repeatedly, in cyclic fashion, to condense hydrogen atoms onto chromospheric structures, CHS (as shown in the lower half of the figure). Alternatively, if excited helium He^* is initially produced in the singlet state (parahelium — electrons in different orientation: spin up/down), emission can immediately occur generating the singlet lines from He I. This scheme accounts for the strong triplet He I transition at 10830 Å observed in the flash spectrum of the chromosphere. Unlike the situation in the gas models, random collisional or photon excitations are not invoked to excite the helium atoms. De-excitation processes would also be absent, helping to ensure the buildup of triplet state orthohelium in this model. This figure, along with its legend, was previously published in [61].

First, HeH^+ and CHS react to form an activated complex: CHS + HeH^+ → CHS-H-He^{+*}. If the expulsion of an excited helium ion (He^{+*}) follows, full transfer of a proton and an electron to CHS will have occurred (top line in Fig. 16). The resulting He^{+*} would be able to relax back to a lower energy state through emission, leading to the well known He II lines in the chromosphere (top right in Fig. 16).

Alternatively, when HeH^+ reacts with CHS, the expulsion of an excited helium atom (He^*) could follow (see Fig. 16) involving the transfer of a proton — but no electron — to the CHS. As a strong Brønsted acid, HeH^+ should permit these reactions (namely: CHS–HHe^{+*} → CHS–H^+ + He^*). Expulsion of an activated helium atom (He^*) can lead to two conditions, depending on whether the electrons within this species are antiparallel (parahelium) or parallel (orthohelium). Within helium, the excited electron is allowed by selection rules to return to the ground state, if and only if, its spin is opposed to that of the ground state electron. As a result, only parahelium can relax back to the ground state: $He^* \rightarrow He + h\nu$. This leads to the HeI lines from singlet helium.

As for the excited orthohelium, it is unable to relax, as its two electrons have the same spin (either both spin up or both spin down). *Trapped* in the excited state, this species can at once react with hydrogen, forming the excited helium hydride molecule, which, like the helium hydride cation, is known to exist [256, 257]: $He^* + H \rightarrow HeH^*$.

Excited helium hydride can react with CHS in the chromosphere, but now resulting in a doubly activated complex: CHS + HeH^* → CHS-H-He^{**}, wherein one electron remains in the ground state and the other electron is promoted beyond the 2S shell.* To relax, the doubly excited He^{**} atom, must permit an electron currently in the 2P or higher orbital, to return to the 2S or 2P orbitals.

The helium D_3 line would be produced by a $3^3D \rightarrow 2^3P$ transition [245, p. 95]. The $2^3P \rightarrow 2^3S$ transition is associated with the strong triplet He I line at 10830 Å [245, p. 95]. Alternatively, a $3^3P \rightarrow 2^3S$ transition produces the triplet He I line at 3890 Å [245, p. 95].

Importantly, since excited orthohelium cannot fully relax back to the ground state, it remains available to recondense with atomic hydrogen in the chromosphere. This results in its continual availability in the harvest of hydrogen. A cyclic process has been created using orthohelium (He^*). The priming of this cycle had required but a single instance where hydrogen was transferred to CHS by HeH^+, without the complementary transfer of an electron (top line in Fig. 16).† In this manner, much like what occurred in the case of molecular hydrogen (§3.4) and the metal hydrides (§3.5), the body of the Sun has been permitted to recapture atomic hydrogen lost to its atmosphere. It does not simply lose these atoms without any hope of recovery [59, 61, 62].

Within the LMH model, the prominence of the helium triplet lines can be elegantly explained. They result from the systematic excitation of helium, first delivered to condensed hydrogen structures by the helium hydride cation (HeH^+), a well-known molecule [247–254] and strong Brønsted acid. The generation of triplet state excited helium can be explained in a systematic fashion and does not require unrealistic temperatures in the corona. It is not an incidental artifact produced by improbably selective excitations generated using

*The possibility that He^{**} could have no electrons in the ground state is not considered.

†The production of Ca II emission lines from CaH had resulted in the transfer of two electrons per hydrogen atom (see §3.5). This can help keep charge neutrality in condensation reactions involving HeH^+.

coronal photons. Organized chemical reactions govern the behavior of helium in the Sun, not random events.

3.7 Fraunhofer Absorption #15

When examined under high spectral resolution, the visible spectrum of the Sun is punctuated by numerous absorption lines, which appear as dark streaks against a brighter background.* These lines were first observed by William Hyde Wollaston in 1802 [258]. They would eventually become known as *Fraunhofer lines* after the German scientist who most ably described their presence [259]. Fraunhofer lines can be produced by many different elements. They manifest the absorption of photospheric light by electrons, contained within gaseous atomic or ionic species above the photosphere, which are being promoted from a lower to a higher energy level.

In 1862, Kirchhoff was the first to argue that the Fraunhofer lines provided evidence for a condensed solar body, *"In order to explain the occurrence of the dark lines in the solar spectrum, we must assume that the solar atmosphere incloses a luminous nucleus, producing a continuous spectrum, the brightness of which exceeds a certain limit. The most probable supposition which can be made respecting the Sun's constitution is, that it consists of a solid or liquid nucleus, heated to a temperature of the brightest whiteness, surrounded by an atmosphere of somewhat lower temperature."* [190, p. 23].

Amongst the most prominent of the Fraunhofer lines are those associated with the absorption of photospheric light by the hydrogen atoms. The preeminent Fraunhofer lines are generated by the Balmer series. These lines are produced when an excited hydrogen electron (N=2) absorbs sufficient energy to be promoted to yet higher levels (Hα N = 2 → N = 3 656.3 nm; Hβ N = 2 → N = 4 486.1 nm; Hγ N = 2 → N = 5 434.1 nm; Hδ N = 2 → N = 6 410.2 nm; etc). They can be readily produced in the laboratory by placing hydrogen gas in front of a continuous light source.

In 1925, Albrecht Unsöld reported that the solar Fraunhofer lines associated with hydrogen did not decrease as expected [260]. He noted intensities across the Balmer series ($H_\alpha = 1$; $H_\beta = 0.73$; $H_\gamma = 0.91$; $H_\delta = 1$) which where highly distorted compared to those expected in a hydrogen gas, as predicted using quantum mechanical considerations ($H_\alpha = 1$; $H_\beta = 0.19$; $H_\gamma = 0.07$; $H_\delta = 0.03$) [260].

Hydrogen lines were known to be extremely broad from the days of Henry Norris Russell and Donald H. Menzel, who had observed them in association with solar abundance [87] and chromospheric studies [205], respectively. Commenting on the strength of the hydrogen Balmer series, Henry Norris Russell would write, *"It must further be born in mind that even at solar temperatures the great majority of the atoms of any given kind, whether ionized or neutral, will be in the state of lowest energy... One non-metal, however, presents a real and glaring exception to the general rule. The hydrogen lines of the Balmer series, and, as Babcock has recently shown, of the Paschen series as well, are very strong in the Sun, though the energy required to put an atom into condition to absorb these series is, respectively, 10.16 and 12.04 volts — higher than for any other solar absorption lines. The obvious explanation — that hydrogen is far more abundant than the other elements — appears to be the only one"* [87, p. 21–22].

In the photospheric spectrum, the hydrogen absorption lines are so intense that the observer can readily garner data from the Lyman (N=1 → N=2 or higher), Balmer (N=2 → N=3 or higher), Paschen (N=3 → N=4 or higher), and Brackett (N=4 → N=6 or higher) series [87, 205, 260–264].

The central questions are three fold: 1) Why are the hydrogen lines broad? 2) Why does hydrogen exist in excited state as reflected by the Balmer, Paschen, and Brackett lines? and 3) Why is the normal quantum mechanical distribution of the Balmer series distorted as first reported by Unsöld [260]?

In the gaseous models, different layers of the solar atmosphere have to be invoked to account for the simultaneous presence of Lyman, Balmer, Paschen and Brackett line profiles in the solar spectrum [261–264]. Once again, as when addressing limb darkening (see §2.3.2), the models have recourse to optical depth [261–264]. These approaches fail to adequately account for the production of the excited hydrogen absorption.

As noted in §3.4, in the setting of the LMH model, excited hydrogen atoms can be produced through condensation reactions occurring in the solar chromosphere. These atoms could be immediately available for the absorption of photons arising from photospheric emission. Hence, condensation reactions provide an indirect mechanism to support the generation of many hydrogen Fraunhofer line. Since these lines are being produced in close proximity to condensed matter, it is reasonable to conclude that their linewidths are determined by their interaction with such materials and not from optical depth and Stark mechanisms (see §3.4). This may help to explain why the intensity of the Balmer lines, as first reported by Unsöld [260], do not vary as expected in gases from quantum mechanical considerations. Unsöld's findings [260] strongly suggest that the population of excited hydrogen atoms is being distorted by forces not known to exist within gases. Once again, this calls attention to condensed matter.

3.8 Coronal Emission #16

As was discussed in §2.3.7, the K-corona is the site of continuous emission which reddens slightly with altitude, but whose general appearance closely resembles the photospheric spectrum [57].† This leads to the conclusion that condensed matter must be present within this region of the Sun [57]. Still, the nature of the corona is more complicated, as the same region which gives rise to condensed matter in the K-

*This proof was first presented as the sixteenth line of evidence [47, 59].

†This proof was first presented as the 31st line of evidence [60, 62].

corona is also responsible for the production of numerous emission lines from highly ionized elements (e.g. FeXII-FeXXV [192]) in the E-corona [60].*

When examined in light of the gaseous solar models, the production of highly ionized species requires temperatures in the million of degrees [192]. Temperatures as high as 30 MK have been inferred to exist in the corona [192, p. 26], even if the solar core has a value of only 16 MK [13, p. 9]. Flares have been associated with temperatures reaching 10^8 K [273], and radio sampling has called for values between 10^8 and 10^{10} K [245, p. 128].

Given the temperatures inferred in attempting to explain the presence of highly ionized atoms in the K-corona, proponents of the gaseous models deny that this region can be comprised of condensed matter. Harold Zirin summarizes the situation best, *"... there is something erroneous in our basic concept of how ionization takes place"* [245, p. 183].

Rather than cause a dismissal of condensed matter, such extreme temperature requirements should lead to the realization that the gaseous models are fundamentally unsound [62]. It is not reasonable to assume that the corona harbors temperatures which exceed those found in the core. Furthermore, to arrive at these extreme values, the corona must somehow be heated. The *"zoo"* [148, p. 278] of possible heating mechanisms is substantial [148, p. 239–251]. According to E.R. Priest, the hypothesized mechanisms are fundamentally magnetic in nature as *"all the other possible sources are completely inadequate"* [273]. The problem for gaseous models can be found in the realization that their only means of producing highly ionized atoms must involve violent bombardment and the removal of electrons to infinity. These schemes demand impossible temperatures.†

It is more reasonable to postulate that elements within the corona are being stripped of their electrons when they come into contact with condensed matter. The production of highly ionized atoms involves electron affinity, not temperature. The belief that the corona is a region characterized by extremely elevated temperatures is erroneous. The cool K-coronal spectrum is genuine. The associated photons are directly produced by the corona itself, not by the photosphere (see §2.3.7).

Moreover, condensed matter can have tremendous electron affinities. This is readily apparent to anyone studying lightning on Earth. Thunderhead clouds have been associated with the generation of 100 keV X-rays [274, p. 493-495], but no-one would argue that the atmosphere of the Earth sustains temperatures of 10^9 K. Lightning can form *"above volcanoes, in sandstorms, and nuclear explosions"* [274, p. 67]. It represents the longest standing example of the power of electron affinity, as electrons are transferred from condensed matter in the clouds to the Earth's surface, or vise versa [274–276].

Metallic hydrogen should exist in the K-corona, as Type-I material has been ejected into this region (see §2.3.8) by activity on the photosphere [58]. Electrical conductivity in this region is thought to be very high [277, p. 174]. Thus, the production of highly ionized elements can be explained if gaseous atoms come into contact with this condensed matter. For example, iron (Fe) could interact with metallic hydrogen (MH) forming an activated complex: MH + Fe → MH–Fe*. Excited Fe could then be ejected with an accompanying transfer of electrons to metallic hydrogen: MH–Fe* → MH–$n\bar{e}$ + Fe^{+n*}. The emission lines observed in the corona are then produced when the excited iron relaxes back to the ground state through photon emission, $Fe^{+n*} \rightarrow Fe^{+n} + h\nu$. Depending on the local electron affinity of the condensed metallic hydrogen, the number of electrons transferred, n, could range from single digits to ~25 [192] in the case of iron.‡

The scheme formulated with iron can be extended to all the other elements,§ resulting in the production of all coronal emission lines. The governing force in each case would be the electron affinity of metallic hydrogen which may increase with altitude. Highly ionized species are not produced through the summation of multiple electron ejecting bombardments. Rather, multiple electrons are being stripped simultaneously, in single action, by transfer to condensed matter. In this manner, the *electron starved* corona becomes endowed with function, *the harvesting of electrons from elements in the solar atmosphere, thereby helping to maintain the neutrality of the solar body* [60].

In this sense, the chromosphere and corona have complimentary action. The chromosphere harvests hydrogen atoms and protons. The corona harvests electrons.¶

As for the transition zone (see Fig. 1.1 in [192]), it does not exist. This region was created by the gaseous models in order to permit a rapid transition in apparent temperatures between the cool chromosphere and hot corona (see [62] for a complete discussion). In the metallic hydrogen model, the apparent temperatures in both of these regions are cool, there-

*The story which accompanies the mystical element coronium (or FeXIV) in the corona and its discovery by the likes of Harkness, Young, Grotian, and Edlén [151–153] has been recalled [265–268]. Wonderful images of the corona have recently been produced from highly ionized iron (e.g. FeX-FeXIV) [269–272].

†It will be noted in §5.5, that the gaseous solar models infer widely varying temperatures within the *same* regions of the corona when analyzing coronal loops (see Fig. 22). How could it be possible to sustain vastly differing values in the *same* region of the solar atmosphere? These findings are indicative that we are not sampling temperature, but rather substructures with distinct electron affinities. These substructures take advantage of a wide array of species to transfer electrons. Evidence for such a solution can be found in Fig. 1.10 of [192] which describes flare substructure and the associated variations in emitting species (arcade emitting in FeXII — spine emitting in FeXXIV and Ca XVII).

‡In this regard, it is important to note that most of the ions present in the *"XUV spectrum are principally those with one or two valence electrons"* [245, p. 173]. This observation is highly suggestive that systematic processes are taking place, not random bombardments.

§A least one electron must remain for line emission.

¶While the corona is primarily composed of metallic hydrogen, as will be seen in §5.4, it can provide a framework to allow for the condensation of hydrogen in non-metallic form.

fore a transition zone serves no purpose [62]. The changes in atomic and ionic compositions observed in the solar atmosphere can be accounted for by 1) the varying ability of molecular species to deliver hydrogen and protons to condensed hydrogen structures in the chromosphere as a function of altitude, and 2) to changes in the electron affinity of metallic hydrogen in the corona.

This scenario resolves, at long last, the apparent violation of the Second Law of Thermodynamics which existed in the gaseous model of the Sun. It is not realistic that the center of the Sun exists at 16 MK [13, p. 9], the photosphere at 6,000 K, and the corona at millions of degrees. A solution, of course, would involve the recognition that most of the energy of the photosphere is maintained in its convection currents and conduction bands [37], not in the vibrational modes responsible for its thermal spectrum and associated apparent temperature. But now, the situation is further clarified. The corona is not being heated — it is cool. No violation of the Second Law of Thermodynamics exists, even if photospheric convection and conduction are not considered.

4 Structural Lines of Evidence

The structural lines of evidence are perhaps the most physically evident to address, as they require only elementary mechanical principles to understand.

4.1 Solar Collapse #17

Should stars truly be of gaseous origin, then they are confronted with the problem of solar collapse.* Somehow, they must prevent the forces of gravity from causing the entire structure to implode upon itself.

Arthur Eddington believed that stellar collapse could be prevented by radiation pressure [9]. Photons could transfer their momentum to stellar particles and thereby support structure. These ideas depend on the existence of radiation within objects, a proposal which is counter to all laboratory understanding of heat transfer. Conduction and convection are responsible for the transfer of energy within objects [70]. It is only if one wishes to view the Sun as an assembly of separate objects that radiation can be invoked.

Eventually, the concept that the Sun was supported exclusively by radiation pressure was abandoned. Radiation pressure became primarily reserved for super-massive stars [13, p. 180-186]. Solar collapse was prevented using *'electron gas pressure'* [13, p. 132], with radiation pressure contributing little to the solution [13, p. 212].

But the idea that *'electron gas pressure'* can prevent a star from collapsing is not reasonable [3, 35, 43, 48]. The generation of gas pressure (see Fig. 17) requires the existence of true surfaces, and none can exist within a gaseous Sun.† When a particle travels towards the solar interior, it can simply undergo an elastic collision, propelling a stationary particle beneath it even further towards the core. Without a surface, no net force can be generated to reverse this process: the gaseous Sun is destined to collapse under the effect of its own gravity [48].

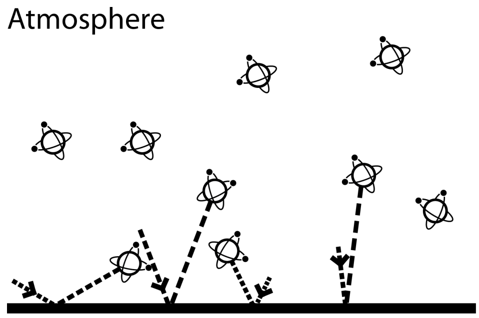

Fig. 17: Schematic representation of the generation of gas pressure. As particles travel towards a real surface, they eventually undergo a change in direction resulting in the creation of a net upwards force.

Donald Clayton, a proponent of the gaseous models, describes the situation as follows, "*The microscopic source of pressure in a perfect gas is particle bombardment. The reflection (or absorption) of these particles from a real (or imagined) surface in the gas results in a transfer of momentum to that surface. By Newton's second law* ($F = dp/dt$)*, that momentum transfer exerts a force on the surface. The average force per unit area is called the pressure. It is the same mechanical quantity appearing in the statement that the quantity of work performed by the infinitesimal expansion of a contained gas is* $dW = PdV$*. In thermal equilibrium in stellar interiors, the angular distribution of particle momenta is isotropic; i.e., particles are moving with equal probabilities in all directions. When reflected from a surface, those moving normal to the surface will transfer larger amounts of momentum than those that glance off at grazing angles*" [14, p. 79]. The problem is that real surfaces do not exist within gaseous stars and *'imagined'* surfaces are unable to be involved in a *real* change in momentum. *'Electron gas pressure'* cannot prevent solar collapse.

Unlike the scenario faced by Eddington with respect to solar collapse, James Jeans had argued that liquid stars were immune to these complications, "*And mathematical analysis shews that if the centre of a star is either liquid, or partially so, there is no danger of collapse; the liquid center provides so firm a basis for the star as to render collapse impossible*" [278, p. 287]. By their very nature, liquids are essentially incompressible. Therefore, liquid stars are self-supporting and a LMH Sun faces no danger of collapse.

*This proof was first presented as the third line of evidence [3,35,43,48].

†Conversely, the extended nature of our atmosphere is being maintained through gas pressure precisely because our planet possesses a real surface. When gas particles strike the Earth's surface, they undergo an immediate change in direction with upward directed velocities. Without the presence of a true surface, a net change in particle velocity cannot occur.

4.2 Density #18

Hot gases do not *self-assemble*.* Rather, they are well-known to rapidly diffuse, filling the volume in which they are contained. As a result, hot gaseous *'objects'* should be tenuous in nature, with extremely low densities. In this respect, hot gases offer little evidence that they can ever meet the requirements for building stars.

In an apparent contradiction to the densities expected in gaseous *'objects'*, the solar body has a substantial average density on the order of 1.4 g/cm^3 [279]. In gaseous models, the Sun is believed to have a density approaching 150 g/cm^3 in its core, but only $\sim 10^{-7}$ g/cm^3 at the level of the photosphere [148]. In this way, a gaseous star can be calculated with an average density of 1.4 g/cm^3. But gaseous models would be in a much stronger position if the average density of the Sun was consistent with that in a sparse gas, i.e. $\sim 10^{-4}$ g/cm^3, for instance. It is also concerning that the average density of the Sun is very much coincident with that observed in the outer planets, even though these objects have much smaller total masses.† The giant planets are no longer believed to be fully gaseous, but rather composed of metallic hydrogen [93–95], suggestions which are contrary to the existence of a gaseous Sun.

The Sun has a density entirely consistent with condensed matter. If the solar body is assembled from metallic hydrogen [35, 39], it is reasonable to presume that it has a somewhat uniform distribution throughout its interior.‡ This would be in keeping with the known, essentially incompressible, nature of liquids.

4.3 Radius #19

Within gaseous models, the Sun's surface cannot be real and remains the product of optical illusions [2, 4, 51].§ These conjectures were initially contrived by the French astronomer, Hervé Faye. In 1865, Faye [280] had proposed that the Sun was gaseous [2, 4] and would write, *"This limit is in any case only apparent: the general milieu where the photosphere is incessantly forming surpasses without doubt, more or less, the highest crests or summits of the incandescent clouds, but we do not know the effective limit; the only thing that one is permitted to affirm, is that these invisible layers, to which the name atmosphere does not seem to me applicable, would not be able to attain a height of 3', the excess of the perihelion distance of the great comet of 1843 on the radius of the photosphere"* [280]. With those words, the Sun lost its true surface. Everything was only *'apparent'* (see §1). Real dimensions, like diameter or radius, no longer held any validity. Nonetheless, Father Secchi considered the dimensions of the Sun to be a question of significant observational importance, despite problems related to their accurate measure [1, p. 200–202, V. I].

Today, the radius of the Sun (~696,342±65 km) continues to be measured [51] and with tremendous accuracy — errors on the order of one part in 10,000 or even 2 parts in 100,000 (see [281] for a table). Such accurate measurements of spatial dimensions typify condensed matter and can never characterize a gaseous object.¶ They serve as powerful evidence that the Sun cannot be a gas, but must be composed of condensed matter.

The situation relative to solar dimensions is further complicated by the realization that the solar diameter may well be variable [282]. Investigations along these lines are only quietly pursued [283], as the gas models are unable to easily address brief fluctuations in solar dimensions. The stability of gaseous stars depends on hydrostatic equilibrium and relies on a perfect mechanical and thermal balance [13, p. 6–67]. Failing to maintain equilibrium, gaseous stars would cease to exist.

Conversely, fluctuating solar dimensions can be readily addressed by a liquid metallic hydrogen Sun, since this entity enables localized liquid/gas (or solid/gas) transitions in its interior (see [48, 51, 52] and §5.1).

4.4 Oblateness #20

James Jeans regarded the high prevalence of binaries as one of the strongest lines of evidence that the stars were liquids [27, 28].‖ Indeed, it could be stated that most of his thesis rested upon this observation. As a spinning star became oblate, it eventually split into two distinct parts [27, 28]. Oblateness can be considered as a sign of internal cohesive forces within an object and these are absent within a gaseous star. As a result, any oblateness constitutes a solid line of evidence that a rotating mass is comprised of condensed matter.

The physics of rotating fluid masses has occupied some of the greatest minds in science, including Newton, Maclaurin, Jacobi, Meyer, Liouville, Dirichlet, Dedekind, Riemann, Poincaré, Cartan, Roche, and Darwin [3]. The problem also captivated Chandrashekhar (Nobel Prize, Physics, 1983) for nine years of his life [284].

Modern studies placed the oblateness of the Sun at 8.77×10^{-6} [287]. Though the Sun appears almost perfectly

*This proof was first presented as the fourth line of evidence [35, 36].

†The Earth has a density of 5.5 g/cm^3; Jupiter 1.326 g/cm^3; Saturn 0.687 g/cm^3; Neptune 1.638 g/cm^3; Uranus 1.271 g/cm^3 [279].

‡Setsuo Ichimaru had assumed, based on the gaseous models, that the core of the Sun had a density of 150 g/cm^3 when he considered that it could be composed of metallic hydrogen [97–99]. He did not address the composition of the solar body or atmosphere.

§This proof was first presented as the 21st line of evidence [51].

¶As a point of reference relative to the accuracy of measurements, machinists typically work to tolerances of a few thousands of an inch. According to a young machinist (Luke Ball, Boggs and Associates, Columbus, Ohio), a *"standard dial caliper is accurate to ± 0.001", and a micrometer provides greater accuracy to ± 0.0001". The Mitutoyo metrology company was founded in 1934, and they produce a digital high-accuracy sub-micron micrometer that is accurate to .00002."*

‖This proof was first presented as the eighth line of evidence [3, 35, 36, 50].

round, it is actually oblate [50].* To explain this behavior, astrophysicists invoked that the Sun possessed a constant solar density as a function of radial position [287]. This proposal is in direct conflict with the gaseous solar models [13, 14] which conclude that most of the solar mass remains within the central core. An essentially constant internal density is precisely what would be required within the context of a liquid metallic Sun [35, 39].

At present, helioseismic measurements (see §6) indicate that the degree of solar oblateness may be slightly smaller [288, 289], but the general feature remains. The degree of solar oblateness may well vary with the solar cycle [290]. As was the case for variations in solar radius (§4.3), these changes pose difficulties for the gaseous models. That the Sun is slightly oblate provides excellent evidence for internal cohesive forces, as seen in condensed matter.

4.5 Surface Imaging #21

With the advent of the 1-m Swedish Solar Telescope (SST), the solar surface has been imaged with unprecedented resolution [100, 291].† This resolution will increase dramatically in a few years when the construction of the Advanced Technology Solar Telescope is completed in Hawaii [104].

Using the SST, scientists report, *"In these pictures we see the Sun's surface at a low, slanting angle, affording a three-dimensional look at solar hills, valleys, and canyons"* [291]... *"A notable feature in our best images of sunspots is that many penumbral filaments, which are isolated from the bulk of the penumbra and surrounded by dark umbra, show dark cores"*... *"Inspection of our images shows numerous varieties of other very thin dark lines in magnetic regions"* ... *"'hairs' that are seemingly emanating from pores into the closest neighbouring granules, 'canals' in the granulation near spots and pores, and running dark streaks crossing penumbral filaments diagonally"* [100].

Since antiquity, solar observers have been fascinated with structure on the surface of the Sun. Now, as telescopic resolution continues to increase, they are documenting, *almost in 3D*, the existence of structure on the solar surface with increased certainty. They resort to words like *'hills'*, *'valleys'*, and *'canyons'* to describe the surface of the Sun and they focus increasingly on substructures, like the dark cores of the penumbra. How can this structural detail be compatible with gases? Structure remains a property of condensed matter and gases can support none. Moreover, if the solar surface is but an *'illusion'*, what point can there be in documenting the nature of these structures? But the problem is even more vexing for the gaseous models, as films are currently being taken of the Sun in high resolution (see Supplementary Materials for [100] on the Nature website), and our *'illusions'* are *behaving* as condensed matter (see §5.1) [292, 293].

Father Secchi, perhaps the most able solar observer of the 19th century, drew with painstaking attention numerous details on the solar surface which he viewed as real [1]. He emphasized that *"there is thus no illusion to worry about, the phenomena that we have just exposed to the reader are not simple optical findings, but objects which really exist, faithfully represented to our eyes using instruments employed to observe them"* [1, p. 35–36, V. II]. The authors of the wonderful SST Nature paper [100] seem to discard illusions, *"We are, however, confident that the dark cores shown here are real"* [100]. Nonetheless, they maintain the language associated with the gaseous models, *"A dark-cored filament could be produced by an optically thin cylindrical tube with hot walls—perhaps a magnetic flux tube heated on the surface by the dissipation of electrical currents"* [100].

Commenting on [100] in light of accepted theory, John H. Thomas states, *"Computer simulations of photospheric magnetoconvection show very small structures, but the simulations have not yet achieved sufficient resolution to determine the limiting size. The horizontal mean free path — in other words, the average distance traveled without interacting — of a photon in the solar photosphere is about 50 km, and so this might be expected to be the smallest observable length scale, because of the smoothing effect of radiative energy transfer. But sophisticated radiative-transfer calculations show that fine structures as small as a few kilometers should in principle be directly observable"* [294].

The problem for the gas models rests in their prediction that the photosphere has a density ($\sim 10^{-7}$ g/cm^3 [148]) which is 10,000 times lower than that of the Earth's atmosphere at sea level — surpassing some of the best vacuums on Earth. Structure cannot be claimed to exist in a vacuum and has never been demonstrated to be associated with the equations of radiation transfer (see [292, 294] and references therein). It is inherently a property of condensed matter, without any need for internal photons. As a result, modeling associated with the analysis of structural entities on the solar surface, which is fundamentally based on ideas of a gaseous Sun [292, 294], are unlikely to be of any lasting value with respect to understanding the complexities of the photosphere. The most elegant solution rests in accepting that these structures are real and comprised of condensed matter.

4.6 Coronal Holes/Rotation #22

Coronal holes (see Fig. 18) are believed to be regions of low-density plasma that open freely into interplanetary space [52,

*As a point of interest, the Southern star Achernar, has a tremendous oblateness which approaches 1.5 [285]. This value cannot be explained using the standard gaseous models wherein most of a star's mass is restricted to the core. As such, scientists have sought to find alternative means to account for this oblateness [286].

†This proof was first presented as the eleventh line of evidence [4, 35, 36, 42]. Solar surface imaging can include frequencies outside visible light. It continues to reveal the presence of new structures, not described in §2. These, and those to come, are included herein as a separate line of evidence as solar surface imaging exposes more structural complexity and temporal evolution.

295, 296].* They are associated with the presence of fast solar winds (see §5.8).

When the Sun becomes active, coronal holes can appear anywhere on the solar surface [52, 295, 296]. In contrast, when it is quiet, coronal holes are viewed as *'anchored'* onto the polar regions of the solar surface [297, p. 10]. This *'anchoring'* constitutes a powerful sign that the Sun is comprised of condensed matter, as this behavior directly implies both long-term structure within the corona and the existence of a true solar surface. *'Anchoring'* requires two distinct regions in the Sun which cooperate with each other to produce *structural restriction*.

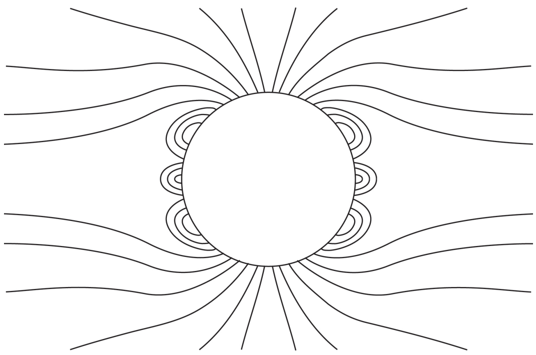

Fig. 18: Schematic representation of coronal holes over the polar caps of a quiet Sun. This figure is an adaptation based on Fig. 2 in [295]. Along with its legend, it was previously published in [52].

The corona possesses *"... a radially rigid rotation of 27.5 days synodic period from 2.5 $R_\odot$ to >15$R_\odot$"* [277, p. 116] as established by the LASCO instrument aboard the SOHO satellite [298]. Rigid rotation of the entire corona strongly suggests that the solar body and the corona possess condensed matter.

Coronal material† contains magnetic fields lines which, in turn, are anchored at the level of the photosphere [62]. *'Anchoring'*, once again, requires structure both within the solar body and within the solar atmosphere. The condensed nature of the corona and coronal structures has already been discussed in §2.3.7, §2.3.8, and §3.8. It will be treated once again in §5.5, and §6.6. The relevant structure of the solar interior will be discussed in §5.1. The presence of *'anchoring'* within coronal holes and the rigid rotation of the corona is best explained by condensed matter.

4.7 Chromospheric Extent #23

Eddington recognized the great spatial extent of the chromosphere and pondered on how this material was supported [9, p. 362].‡ At the time, he knew that chromospheric emission lines (see §3.4, §3.5, and §3.6) could extend up to 14,000 km [9, p. 362]. For Eddington, the answer to chromosphere chromospheric extent rested upon radiation pressure, but the solution would prove insufficient [62].

Bhatnagar and Livingston provide a lucid presentation of the chromospheric scale height problem within the context of the gaseous models [277, p. 140–145]. They recall how initial *'hydrostatic equilibrium'* arguments could only account for a density scale height of 150 km [277, p. 141]. In order to further increase this scale height to the levels observed, it was hypothesized that the chromosphere had to be heated, either through turbulent motion, wave motion, magnetic fields, or 5-minute oscillations [277, p. 140–145]. The entire exercise demonstrated that the spatial extent of the chromosphere represented a significant problem for the gaseous models. The great solar physicist Harold Zirin has placed these difficulties in perspective, *"Years ago the journals were filled with discussions of 'the height of the chromosphere'. It was clear that the apparent scale height of 1000 km far exceeded that in hydrostatic equilibrium. In modern times, a convenient solution has been found — denial. Although anyone can measure its height with a ruler and find it extending to 5000 km, most publications state that it becomes the corona at 2000 km above the surface. We cannot explain the great height or the erroneous models... While models say 2000 km, the data say 5000"* [193].

Obviously, a gas cannot support itself [62]. Hence, the spatial extent of the chromosphere constitutes one of the most elegant observations relative to the existence of a condensed solar photosphere. Within the context of the LMH model [35, 39], the Sun possesses a condensed surface. This surface provides a mechanism to support the chromosphere: gas pressure (see Fig. 17) — the same phenomenon responsible for the support of the Earth's atmosphere [48].

It was demonstrated in §4.1, that electron gas pressure cannot prevent a gaseous star from collapsing onto itself, being that these objects lack real surfaces. However, a liquid metallic hydrogen Sun has a real surface, at the level of the photosphere. When a gaseous atom within the solar atmosphere begins to move towards the Sun, it will eventually strike the surface. Here, it will experience a change in direction, reversing its downward vertical component and thereby placing upward pressure on the solar atmosphere, as displayed in Fig. 17. Gas pressure can simply account for the spatial extend of the chromosphere in condensed solar models [35, 39]. Moreover, under this scenario, the chromosphere might be supported by the escape of gaseous atoms from the solar interior as manifested in solar activity (see §5.1). This provides an acceptable mechanism in the condensed models, as they do not need to maintain the hydrostatic equilibrium essential to the gaseous Sun. In any event, chromospheric heat-

*The anchoring of coronal holes was first presented as the 22nd line of evidence [52], while the rigid rotation of the corona was once treated as the 33rd [62]. These two proofs, being closely related to one another, have now been combined.

†See the wonderful Fig. 106 in [1, p. 310, V. I] relaying the corona during the eclipse of July 8, 1842

‡This proof was first presented as the 34th line of evidence [62].

ing, from turbulent motion, wave motion, magnetic fields, or 5-minute oscillations [277], is not required to support the great spatial extent of the chromosphere in the LMH model.

4.8 Chromospheric Shape #24

Secchi had observed that the diameter of the observable Sun varied with filter selection (blue or red) during a solar eclipse [1, p. 320, V. I]. Currently, it is well established that the dimensions of the chromosphere are perceived as vastly different, whether it is studied in Hα, or using the HeII line at 30.4 nm [243, Fig. 1]. The chromosphere also appears to be prolate [243]. This prolateness has been estimated as ΔD/D = 5.5×10^{-3} in HeII and 1.2×10^{-3} in Hα — more extended in polar regions than near the equator [243]. The shape of this layer has been demonstrated to be extremely stable, with no significant variation over a two year period [243].*

The prolate nature of the chromosphere and the extended structure which the Sun manifests above the polar axis cannot be easily explained by the gaseous models. A gaseous Sun should be a uniform object existing under equilibrium conditions, with no means of generating preferential growth in one dimension versus another. When the Sun is quiet, the greater extent of the chromosphere above the poles is associated with the presence of large anchored coronal holes in this region §(4.6). Coronal holes, in turn, manifest the presence of fast solar winds (see §5.8). A link to the fast solar winds is made in the gaseous Sun [243], despite the recognition that the origins of these winds (§5.8), and of the coronal holes with which they are associated (§4.6), remains an area of concern within these models [48, 52].

Even the oblate nature of the solar body had provided complications for the gaseous Sun (§4.4). This oblateness could be explained solely on internal cohesive forces and rotational motion in the LMH model (§4.4). But, the prolate nature of the chromosphere reflects something more complex.

According to the LMH model, fast solar winds (§5.8) are produced when intercalate atoms (see §5.1 Fig. 19) are actively being expelled from the lattice of the solar body [48, 52]. During this processes, some hydrogen is ejected, but unlike the other elements, it is often recaptured to help maintain the solar mass. In this respect, the solar chromosphere has been advanced as a site of hydrogen recondensation in the solar atmosphere (see §5.4, §5.6 and [59,61]). It appears prolate because, at the poles, more hydrogen is being expelled. Thus, more is recaptured over a greater spatial area. In analogous fashion, the corona has been designated as a site of electron recapture within the Sun [60]. With increasing distance from the solar surface, coronal atoms are increasingly stripped of their electrons. This is an electron affinity problem, wherein metallic hydrogen in the solar atmosphere scavenges for electrons and strips them from adjacent atoms [60]. Therefore, the chromosphere [59] and corona [60] act in concert to recapture protons and electrons, bringing them back onto the solar surface.

In §3.4, it was proposed [59] that the Hα emission is the direct result of the recondensation of atomic hydrogen, delivered by molecular hydrogen, onto larger condensed hydrogen structures, CHS, within the chromosphere. HeII emission results from the recondensation of atomic hydrogen, delivered by the helium hydride molecular cation [61], onto these structures (see §3.6).

In the lower chromosphere, neutral molecular hydrogen exists and can deliver atomic hydrogen with ease, resulting in Hα emission. However, with increasing height, it becomes more scarce, as the corona captures electrons. Once deprived of its sole electron, hydrogen cannot emit.

In contrast, with increased elevation, the helium hydride cation can become more abundant, as atomic helium can now harvest lone protons. Of course, neutral helium hydride in the ground state is not stable [256, 257]. Helium must first capture a lone proton (or first lose an electron to become He^+ and capture neutral hydrogen) to form the stable molecule. This readily occurs with increased height. Thus, HeII emissions are seen at the greatest chromospheric elevations. Since the helium hydride cation produced at these elevations can migrate towards the solar surface, one is able to observed HeII lines all the way down to the level of the photosphere.

Such an elegant account, exploiting chemical principles to understand line emission, cannot be framed by the gaseous models relative to the prolate nature for the chromosphere. This includes the possible causes for the differential spatial extent of Hα versus HeII lines (see Fig. 1 in [243]).

5 Dynamic Lines of Evidence

The dynamic lines of evidence involve time or orientation related changes in solar structure, emission, flow, or magnetic field. Along with many of the structural (§4) and helioseismic (§6) lines of evidence, they are amongst the simplest to visualize.

5.1 Surface Activity #25

The surface of the Sun is characterized by extensive activity.† The solar surface is often viewed as *'boiling'*, or as a *'boiling gas'*. But, gases and a gaseous Sun are unable to *'boil'*. Gases are the result of such actions. Only liquids can boil, while

*To fully understand this proof, it is necessary to simultaneously consider the origins of surface activity (§5.1), coronal holes (§4.6), solar winds (§5.8), Hα emission (§3.4) and HeII emission (§3.6). If the reader believes it difficult to follow, he/she may wish to move to other lines of evidence and return to this section once a more complete picture has been gained. This proof is listed as a structural proof (§3), even though it results from dynamic (§5) and spectroscopic (§3) processes, because it is expressed as the steady state appearance of the chromosphere when the Sun is quiet. In 1997, the sunspot number was near minimum and the data presented in [243] was acquired at that time.

†This proof was first presented as the ninth line of evidence [35, 36].

solids sublime.*

Since gases cannot boil, in order to explain activity on the solar surface, the gaseous models must have recourse to magnetic fields and flux tubes. In the case of sunspots (§2.3.3 [4, 40, 45]), faculae (§2.3.5 [45]), and magnetic bright points (§2.3.5), these fields are located within the solar body. In the case of the chromosphere (§5.6), flares (§2.3.8), and coronal mass ejections (§2.3.8), they arise from the corona. The arguments are fallacious, as magnetic fields themselves depend on structure for formation. Unable to account for their own existence (see §5.3), they cannot be responsible for creating such features within a gaseous medium.

The only prominent active features of the Sun, whose formation appears not to be inherently tied to magnetic fields, are granules (§2.3.4 [40, 45]). These are thought to be generated by subsurface heat which is being transported to the upper visible layers [40, 118–122]. A change in *'gas density'* is required within the photospheric vacuum.

In actuality, those who model granules in the laboratory (see [40] for a detailed review) understand that they are best represented as the products of Bénard convection [314–318], a process dominated by surface tension, not buoyancy [118, p. 116]. The gaseous models, unable to provide for a real surface on the Sun, must reject Bénard convection. The problem is further complicated with the realization that granules obey the 2D laws of structure (see §2.3.4) and that explosive phenomena, associated with *'dark dot'* formation, can be explained solely on the basis of structural considerations [126] (see §2.3.4). To add to the suspension of disbelief, proponents of the gaseous models maintain that the photosphere exists at the density of an ultra-low pressure vacuum ($\sim 10^{-7}$ g/cm^3 [148]). With respect to surface activity, all efforts by the gaseous models to understand the observed phenomena can be seen to collapse, when faced with the simple challenge that their solar surface is only an *'illusion'* [4]. Scientists are confronted with the intellectual denial of objective reality.

The LMH model [35, 36] can account for solar activity, since it allows for structure and takes advantage of the consequences. Granular convection can be explained with ease, as a LMH Sun possesses a true surface and the associated tension required for Bénard convection [314–318].

The emissive behavior of the Sun (see §2.3) strongly argues that the photosphere is comprised of a layered structure much like that found in graphite (see Fig. 2) and first proposed in metallic hydrogen [39] by Wigner and Huntington [88]. Layered materials like graphite are known to form intercalation compounds [48, 79–83] when mixed with other elements (see Fig. 19). In the case of metallic hydrogen, this implies that the non-hydrogen elements occupy interlayer lattice points [48], while the hexagonal hydrogen framework remains intact. It is the science of intercalation compounds which is most closely linked to the understanding of solar activity [48].

Within graphite, the diffusion of elements across hexagonal planes is hindered (see [48] for references), while diffusion within an intercalate layer is facilitated. The same principles are being invoked within the layered metallic hydrogen layers thought to exist in the Sun. Graphite intercalation compounds [79–83] are known to undergo exfoliation, an often violent process (see [79, p. 9] and [83, p. 406], where sudden phase transitions in the intercalation region from condensed to gaseous results in the expulsion of the intercalate atoms. In the laboratory, exfoliation can be associated with a tremendous expansion of lattice dimensions, as the gaseous expansion of the intercalate layers acts to greatly increase the separation between groups of hexagonal planes [79–83].

It is the process of exfoliation which can guide our understanding of solar activity. Exfoliation can be seen to result in the active degassing of the intercalation regions existing within the Sun. When the Sun is quiet, it is degassing primarily at the poles. This results in the fast solar winds (see §5.8) and coronal holes (see §4.6 [52]) in this region. It leads to the conclusion that the hydrogen hexagonal planes in the polar convection zones† tend to be arranged in a direction which is orthogonal to the solar surface.

However, in the equatorial convection zones, the hexago-

*Descriptions of a Sun which is *'boiling'* can be found throughout the printed word. Examples occur in 1) children's books [299], 2) popular writings [300, 301], 3) university level communications [302–305], 4) scientific news articles [306, 307], or 5) scholarly publications [115, 308–313]: 1) *"The sun is a boiling mass of hot gasses"* [299, p. 21], 2) *"It shows rather clearly that the Sun is a boiling mass of energy, vastly violent and constantly changing"* [300]; *"Convection is also at work transferring energy from the radiative zone to the photosphere, with a vertical boiling motion"* [301], 3) *"The surface of the Sun shows us a pattern of boiling gas arranged in a distinctive cellular pattern known as granulation"* [302]; *"Solar plasma emitted from the Sun is a boiling off of the Sun's atmosphere"* [303]; *"It is easy to think of the sun as benign and unchanging, but in reality the sun is a dynamic ball of boiling gases that scientists are only beginning to understand"* [304]; *"Our Sun is an extremely large ball of bubbling hot gas, mostly hydrogen gas"* [305], 4) *"We don't yet have a model that explains these hills"* [Jeffrey R.] *Kuhn said, although he suspects that they are caused by the interaction of boiling gas and the sun's powerful magnetic field"* [306]; *"The researchers found that, as expected, this tumultuous region resembles a pot of boiling water: hot material rises through it, and cooler gases sink"* [307], 5) *"Under poor to fair seeing conditions, sometimes the solar limb appears boiling, this gives some idea about the degree of air turbulence"* [115, p. 54]; *"The surface of the Sun boils in an active manner as the result of the continuous production of energy inside the Sun"* [308]; *"The hot corona boiling off the surface of the Sun toward the cold void of interplanetary space constitutes the solar wind"* [309]; *"The current general idea on the global balance . . . is that energy conducted down from the low corona must 'boil off' mass from the chromosphere . . . "* [310]; *"Near its surface, the Sun is like a pot of boiling water, with bubbles of hot, electrified gas — actually electrons and protons in the forth state of matter known as "plasma" — circulating up from the interior, rising to the surface, and bursting out into space"* [311]; *"The sun is a churning mass of hot ionized gas with magnetic fields threading their way through every pore and core, driven by energies boiling out from the interior where the fusion of hydrogen into helium at a temperature of 15 million K liberates the nuclear energy that keeps the cauldron boiling"* [312]; *"The magnetic field guides these flows, thus influencing on the average the radial distribution in the 'boiling' layer"* [313].

†A solar layer beneath the photosphere.

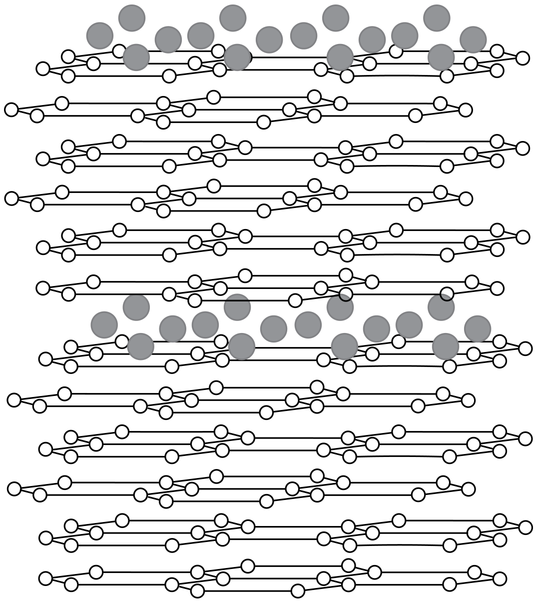

Fig. 19: Schematic representation of a proposed metallic hydrogen intercalation compound, wherein protons occupy the hexagonal lattice planes and non-hydrogen elements are located in the intercalation region. Intercalation compounds are characterized by a *'stage index'*, n, which accounts for the number of hexagonal planes between intercalate layers. In this case, n=6. This figure was previously published as Fig. 3 in [48].

nal hydrogen planes are hypothesized to be oriented parallel to the solar surface. Under the circumstances, atoms in the intercalation regions cannot freely diffuse into the solar atmosphere. They remain essentially *trapped within the Sun*, as reflected by the presence of slow solar winds above the equator. Over half the course of the eleven year solar cycle, intercalate elements slowly increase in number until, finally, the Sun becomes active (see Fig. 15) and exfoliative processes begin. The intercalate atoms begin to break and displace the hexagonal hydrogen planes, as they work their way beyond the confines of the photosphere. Coronal holes become visible at random locations throughout the Sun, indicating the reorientation of hydrogen planes in the interior. With time, the Sun degasses its equatorial region and returns to the quiet state.

In this regard, the series of images displayed in Fig. 15 are particularly telling, as they illustrate that helium levels in the lower solar atmosphere increase significantly with solar activity (examine carefully the periphery of the central image obtained in 2001 compared with images obtained in 1996 or 2005).* The Sun appears to be degassing helium, as previously concluded [48]. This further strengthens the argument that it does not, as popularly believed, possess large amounts of helium in its interior (see [47] for a detailed discussion). Rather, careful observation of the solar cycle reveals that the Sun must be comprised primarily of hydrogen, as it constantly expels other elements from its interior. The notable exception, as was seen is §3.3, relates to lithium [54].†

Relative to solar activity, the liquid metallic Sun allows for the buildup of true pressure in its interior, as intercalate elements enter the gas phase. This could account for changes in solar dimension (§4.3) and shape (§4.4, §6.3) across the cycle. It also explains the production of solar flares in accordance with ideas coined long ago by Zöllner [3, 189]. In a robust physical setting, mechanical pressure is all that is required, not energy from the corona. The same can be said of prominences, whose layered appearance (Fig. 20) highly suggests that they are the product of exfoliative forces within the Sun. Prominences reflect the separation of entire sheets of material from the Sun, exactly as found to occur when exfoliative forces act within graphite [48].

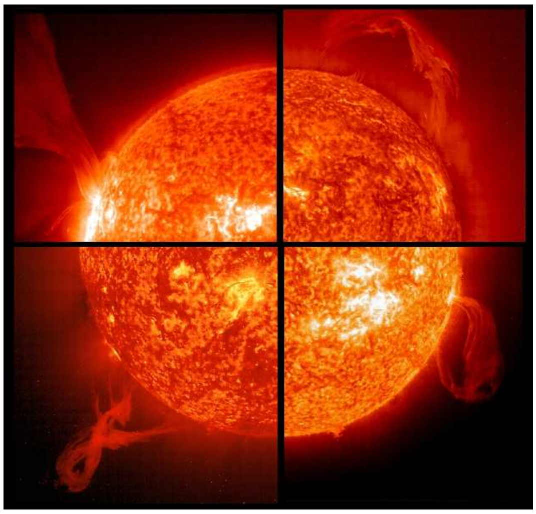

Fig. 20: An assembly of solar images obtained in the HeII line at 30.4 nm displaying the layered appearance of prominences. NASA describes this image as follows, *"A collage of prominences, which are huge clouds of relatively cool dense plasma suspended in the Sun's hot, thin corona. At times, they can erupt, escaping the Sun's atmosphere. For all four images, emission in this spectral line of EIT 304Å shows the upper chromosphere at a temperature of about 60,000 degrees K. The hottest areas appear almost white, while the darker red areas indicate cooler temperatures. Going clockwise from the upper left, the images are from: 15 May 2001; 28 March 2000; 18 January 2000, and 2 February 2001."*. Courtesy of SOHO/[EIT] consortium. SOHO is a project of international cooperation between ESA and NASA. (http://sohowww.nascom.nasa.gov/gallery/images/promquad.html — Accessed on 9/20/2013).

*Best performed using the high resolution image on the NASA SOHO website: http://sohowww.nascom.nasa.gov/gallery/images/large/304cycle.jpg.

†Deuterium and tritium, as hydrogen isotopes, should remain in the hexagonal proton planes. Like lithium, within a LMH model of the Sun, they should be retained within the solar body, with only small numbers escaping in the solar winds.

5.2 Orthogonal Flows #26

The orthogonal nature of material flow in the photosphere and corona (see Fig. 21) provides one of the simplest and most elegant lines of evidence that the Sun is comprised of condensed matter.* In 1863, Carrington established the differential rotation of the photosphere [67, 68]. His studies revealed that solar matter, at the level of the photosphere, experiences a net displacement in a direction parallel to the solar surface. Yet, solar winds (§5.8) are moving radially away from the Sun. This orthogonal flow of matter at the interface of the photosphere and the atmosphere just above it demands the presence of a physical boundary. Such a surface is unavailable in the gaseous models, but self-evident in a liquid metallic hydrogen setting.

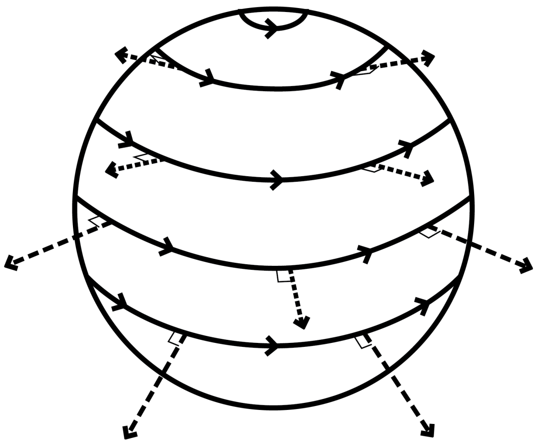

Fig. 21: Schematic representation of the orthogonal photospheric and coronal flows associated with Carrington's differential rotations [67] and the solar winds.

5.3 Solar Dynamo #27

As first noted by George Ellery Hale [107], the Sun possesses strong magnetic fields which can undergo complex windings and protrusions [12].† Magnetic fields are ubiquitous on the solar surface and within the corona. They are not manifested solely in sunspots (§2.3.3). As seen in §2.3.5, strong fields can be observed in faculae and magnetic bright points, while weak fields are present above the granules (§2.3.4) and in coronal structures (§2.3.8).

Within the context of the gaseous models, solar magnetic fields are believed to be produced by the action of a powerful solar dynamo [319, 320] generated at the base of the convection zone near the tachocline layer, well beneath the solar photosphere [12]. A dynamo represents a self-sustained amplification of magnetic fields, produced in conjunction with flow in conducting fluids. In the laboratory, they are studied using liquid metals, typically molten sodium [321–324]. Dynamo behavior must always involve the flow of conductive fluids across magnetic fields. This, in turn, *"induces electrical currents, which, under appropriate flow and magnetic field configurations, can sustain the field against dissipation"* [319].

Perhaps the greatest driving force for understanding the behavior of dynamos in the laboratory has been the presence of planetary and stellar magnetic fields [319–324]. It is not reasonable to apply these studies to a gaseous Sun.

All dynamo laboratories rely on the use of molten sodium. This substance acts as an incompressible conductive liquid metal [321–324].‡ To generate dynamo effects under experimental conditions, flow is typically induced into the metal using mechanical devices like pumps or turbines [321–324]. External induction coils are present which can provide initial magnetic fields to help either "seed" or "drive" the studies [321–324].

It is important to note that macroscopic structure is being imposed in these systems. In every case, the flow of liquid metallic sodium is being confined and directed by structure (tubes, vats, canisters) [321–324]. Insulating materials are always present, whether provided by the presence of pressurizing argon at 80 p.s.i. in a vat [321, 322] or by the inability of molten sodium to direct its own flow when propelled through pipes [323, 324]. Experimental geometries are carefully selected (see e.g. [323, Fig. 1]), including the location of induction coils [321, 322]. Mechanical devices are providing energy to drive these systems and external static magnetic fields supplement the sampling.§

In this respect, Lowe and Wilkinson constructed the first working model of a geomagnetic dynamo [328]. It was composed of solid iron alloy cylinders, rotating within a casting of the same material, wherein a small amount of mercury maintained the required electrical contact [328]. In relaying this design, Lowe and Wilkinson insisted that, *"Self-exciting dynamos are very common on the surface of the Earth, but these rely on the insulation between wires to direct the induced currents into an appropriate path; they are multiply connected"* [328].

These conditions are unlike those in gaseous stars which, by their very nature, are devoid of structure, have no ability to *"direct the induced currents into an appropriate path"* [328], and are incapable of acting as insulators. The situation has been summarized as follows, *"Whereas technical dynamos consist of a number of well-separated electrically conducting parts, a cosmic dynamo operates, without any ferromagnetism, in a nearly homogeneous medium"* [324]. With these

*This proof was first presented as the tenth line of evidence [35, 36].

†This proof was first presented as the twelfth line of evidence [35].

‡Conveniently, the density of liquid metallic sodium ($\rho \sim 0.927$ g/cm^3 [325, p. 4–128]) approaches that hypothesized to exist at the tachocline layer in the gaseous models of the Sun ($\rho \sim 0.2$ g/cm^3 [326]).

§Much like in medicine, where MRI can be performed using only the Earth's magnetic field (∼0.5 gauss) [327], it is impossible to perform dynamo experiments within the laboratory in the absence of an initial ambient static field magnetic field, as has been recognized (e.g. [323]).

words, astrophysical dynamos fell outside the realm of experimental science, precisely because they are thought to exist in objects, like gaseous stars, unable to impart a physical architecture.

Astrophysics cannot hope that magnetic fields impart *'illusionary'* details and emissive properties to photospheric objects (e.g. sunspots and faculae), while at the same time requiring that real structure exists in a gaseous Sun. This structure must somehow enable the formation of powerful magnetic fields and the buildup of a solar dynamo. The fact remains that the generation of strong magnetic fields on Earth always requires the action of condensed matter. As they have no structure, gases are unable to generate magnetic fields on a macroscopic level. They are simply subject to their action. It is improper to confer upon gases behavior which cannot even be approached in the laboratory.

It is hard to envision that hydrogen in non-metallic form, as is currently hypothesized to exist in the gaseous stars, will be able to match the conductivity observed in a real metal (see Fig. 2 in [329]). Gases obviously cannot possess conduction bands and, therefore, lack the central element required to generate powerful magnetic fields on Earth. At the melting point, liquid sodium has a conductivity ($\sim 10^7\,\Omega^{-1}\,\mathrm{m}^{-1}$ [321–324]) which very much approaches that observed in the solid [321–324]. Near this point and in the solid state, conduction bands are responsible for the conductivity measured in sodium.* Hence, it should not be surprising that, just as the metal melts, some quantum mechanical conditions involved in forming these conduction bands remains (i.e. there remains some interatomic order). Otherwise, a substantial change in conductivity would be evident.

With all these factors in mind, it is reasonable to suggest that the structural lattice present in liquid metallic hydrogen provides a superior setting to account for dynamo action in the Sun. Metallic hydrogen should be able to support real structure. Protons would occupy the hexagonal planes (see Fig. 2) and electrons flow in the conduction bands necessary to generate magnetic fields. A LMH Sun should display a density, throughout its interior, similar to molten sodium. Conductive paths could be set up in the hexagonal hydrogen (i.e. proton) planes which can benefit from the insulating action of intercalate elements (see Fig. 19). As a direct consequence, changes in the dynamo and in the magnetic field intensity, in association with the solar cycle, can be accounted for as a byproduct of exfoliative forces (see §5.8). When the intercalate elements are expelled from the Sun, conductive shorts are created between hexagonal hydrogen planes which were once insulated from one another. This provides a mechanism to both build and destroy the solar dynamo. Furthermore, by turning to this substance as a solar building block, laboratory dynamo experiments become linked to a substance which may come to have great importance on Earth [92, 98], not only in the distant stars.

*Thermal vibrations can lower conductivity as temperatures are increased, but this effect is neglected in this case since both solid and liquid phases can exist at the melting point. Thus, any effect of thermal vibrations should be similar at this temperature in both phases.

5.4 Coronal Rain #28

Innocuous findings can lead to the greatest discoveries.† In this respect, coronal rain [330–333] will not present an exception. This subtle effect consists of *"cool and dense matter"* which is *"ubiquitous"* within the solar atmosphere and which is constantly falling towards the solar surface [330–333]. It is said to be composed of a *"a myriad of small blobs, with sizes that are, on average 300 km in width and 700 km in length"* [333]. When these aggregate, they produce *showers* [333]. Coronal rain has been associated with coronal loops and attempts have been made to link its existence to loop substructure [334].

As coronal rain falls towards the surface, its rate of descent does not match that expected from gravity considerations alone [333]. From the standpoint of the gaseous solar models, it appears that coronal rains and showers are retarded by the effects of gas pressure in the solar atmosphere [333]. These models rely on cycles of heating and condensation to explain coronal rain [332, 333]. But these arguments are not consistent with the belief that the lower chromosphere has a density of only $\sim 10^{-12}$ g/cm^3 [115, p. 32] and that gas pressure cannot exist (§4.1) in these models. How can condensation take place within a hot corona (see §3.7) while maintaining a gaseous state, which even at photospheric densities, would only be $\sim 10^{-7}$ g/cm^3 [148]? How can a vacuum retard the rate of descent of these particles? With respect to the existence of coronal rain, the gaseous models of the Sun simply lack the necessary flexibility to provide a reasonable account of this phenomenon.

Alternatively, the LMH model [35, 39], has advanced that condensed matter populates the outer solar atmosphere (see §2.3.6, §2.3.7, §2.3.8, §3.4, §3.5, §3.6, §3.8, §4.6, §4.7, §4.8, §5.5, §5.6, §5.7, and §6.6). Cool/dense coronal and chromospheric layers consequently stand as pillars of this model [56–60]. In this regard, the presence of coronal rain can be more readily explained if one permits true condensation to occur within the solar atmosphere.

As highlighted in §2.3.7 and §2.3.8, the K-corona should be viewed as a region containing diffuse metallic hydrogen [57, 60]. However, given the lack of pressure which exists in the K-corona, this metallic hydrogen cannot regenerate itself. Rather, coronal metallic hydrogen has entered the solar atmosphere after being expelled from the solar body during active periods (see §2.3.8, §5.5, §6.6 and [57, 58, 60]).

Though coronal LMH would be unable to self-regenerate, it should be able to provide a surface upon which other materials could condense. This appears to be what is happening with coronal rain.

†This proof was first presented as the 23rd line of evidence [53].

In this regard, it is important to note that coronal rain is usually visualized in Hα and CaII [334]. These emission lines are chromospheric in nature (see §3.4 and §3.5). Their use in detecting coronal rain strongly suggests that this material, unlike the coronal loops (§5.5) with which it is often associated [334], is actually condensing chromospheric material.*

Thus, much like water vapor on Earth condenses in the morning on the grass, hydrogen, in non-metallic form, appears to generate a dense condensate onto the coronal metallic hydrogen framework. This could explain why coronal rain can been seen flowing down coronal loops [334]. As the two substances are distinct, the hydrogen condensate slowly drifts back down to rejoin the solar surface. Since coronal rain remains attracted to the metallic hydrogen surfaces of the corona, it is unable to simply respond to the forces of gravity and its descent appears to be retarded.

Consequently, the analysis of coronal rain and its behavior appears to provide wonderful examples of the interplay between structure and function within the solar atmosphere. It strongly suggests that two distinct forms of condensed hydrogen are present in this region: 1) dense molecular hydrogen in the chromosphere [92] and 2) metallic hydrogen in the corona. Coronal rain is assisting in the harvest of hydrogen atoms from the corona. In unison, the metallic hydrogen framework, upon which it is condensing, acts to scavenge electrons from non-hydrogen atoms [56–60], which it could channel either to the solar body, or directly to coronal rain. In this manner, the corona functions to help preserve both the mass and charge balance of the Sun.

5.5 Coronal Loops #29

Coronal loops can be readily observed, both in the continuum [178–180] (see §2.3.8) and using distinct atomic emission lines (see §3.5 and §3.6), as shown in see Fig. 22. They represent *"inhomogeneous structures"*, which appear to be attached to the solar surface and which can extend well into the outer atmosphere [335, p. 83–84]. They can be relatively small (1 Mm in length and 200 km thick) or have great physical extent (several million meters to *"a substantial fraction of the solar radius"* with diameters of 1.5 Mm) [336]. While loops do not seem to possess substructure at the resolutions currently available [336], they may display such features on scales of about 15 km [336], a value well beyond current resolutions. Based on the analysis of coronal rain, it has been suggested that coronal loops have substructures smaller than 300 km [334].

As discussed in §5.4, coronal loops are associated with the presence of coronal rain. In this regard, the former may well represent a metallic hydrogen framework within the solar atmosphere unto which chromospheric matter, like coronal rain, can condense. This would appear to be confirmed in Fig. 22, as both chromospheric lines (see §3.4, §3.5, §3.6) and coronal lines (see §3.8) can be detected within coronal loops.

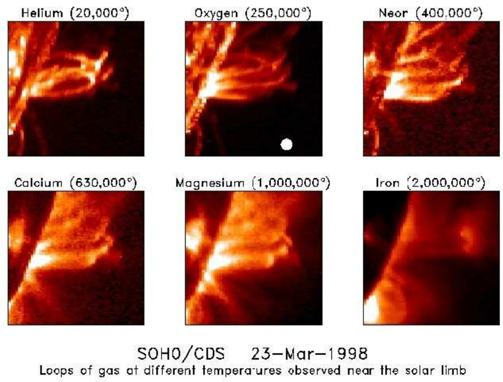

Fig. 22: Coronal loops visualized in helium, oxygen, neon, calcium, magnesium, or iron. Temperatures associated with each image have been inferred from the gaseous solar models. They correspond to 20,000 K, 250,000 K, 400,000 K, 630,000 K, 1,000,000 K, and 2,000,000 K, respectively. NASA describes this image as follows, *"CDS can produce images of the Sun at many wavelengths. In addition to hydrogen, the Sun's atmosphere contains atoms of common elements like helium, oxygen and magnesium. In the high temperature conditions of the Sun's atmosphere, these atoms emit light at different wavelengths depending on the temperature of the gas containing them. Therefore by tuning into different wavelengths we can make images of material which is at different temperatures. This capability is illustrated in the picture above, where CDS has taken images of magnetic loops of material which extend high into the Sun's atmosphere. These loops have been rendered more easily visible by observing them when they occur near the limb of the Sun, and hence they are highlighted against the dark background of space. The elements and their characteristic temperatures are indicated on the individual images. One of the surprises that the new SOHO/CDS data have produced is to show that loops at different temperatures can co-exist in the same regions of the Sun's atmosphere. The white disk plotted on the oxygen image shows the Earth to the same scale."* Courtesy of SOHO/[CDS] consortium. SOHO is a project of international cooperation between ESA and NASA. (http://sohowww.nascom.nasa.gov/gallery/SolarCorona/cds015.html — Accessed on 9/29/2013).

Coronal loops hold an interesting line of evidence for condensed matter. It has been observed that *"the hydrostatic scale height... has always the same vertical extent, regardless of how much the loop is inclined, similar to the water level in communicating water tubes with different slopes"* [335, p. 84] (see Fig. 23).

The vertical height to which some coronal loops appear filled with matter does not change depending on inclination. The loop is containing matter which behaves as a liquid. Conversely, if the loop was merely plasma, the effects of vertical extent on loop appearance would be difficult to justify.

In this regard, it may well be that the manner in which

*Chromospheric matter is likely to be comprised of condensed matter where molecular interactions between hydrogen atoms persist [92].

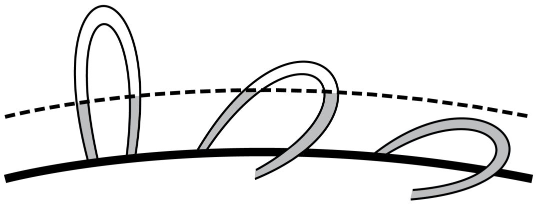

Fig. 23: Schematic representation of the vertical extent of scale height (dashed line) in coronal loops. Material fills the loop up to the scale height. If the loop is significantly inclined from the vertical axis, then it can be somewhat evenly filled with matter. The analogy can be made with water filling a tube which is more or less inclined [335, p. 84].

coronal loops appear to *'fill'* with height might represent a build up of condensed hydrogen onto these structures. As the loops assume an increasingly vertical position, material of a chromospheric nature should slowly settle towards the base of these structures, as it makes its descent down to re-enter the solar interior (see §3.4, §3.5, §3.6). Gaseous solar models are unable to rival this explanation.

5.6 Chromospheric Condensation #30

As discussed briefly in §3.4, the chromosphere is filled with spicules [337] which seem to extend as disoriented hair beyond the surface of the Sun.* As demonstrated in Fig. 24, spicules can be observed in Hα. They can also be seen in other chromospheric emission lines, including those from calcium and helium (see §3.5, §3.6 and [150, p. 8]).

The gaseous models of the Sun have no simple means to account for the formation of these structures.† Proponents of these models have expressed that two classes of spicules exist. Type II spicules are short-lived (10-150s), thin (<200 km), and said to fade [338]. Type I spicules have a 3–7 minute lifetime and move up and down [338]. It has been stated that Type II spicules might be responsible for heating the corona [338], but this claim, along with the very existence of Type II spicules, has been challenged [339]. Nonetheless, despite the densities brought forth, spicules are still believed to be propelling matter into the corona.

Counter to these ideas, the metallic hydrogen model holds that spicules are the product of condensation reactions (see §3.4, §3.5, §3.6 and [59, 61]). They enable hydrogen atoms, gathered in the solar atmosphere, to rejoin the solar body. The greatest clues for such a scenario come from the analysis of spicular velocities which appear to be essentially independent of gravitational forces [209–215].‡

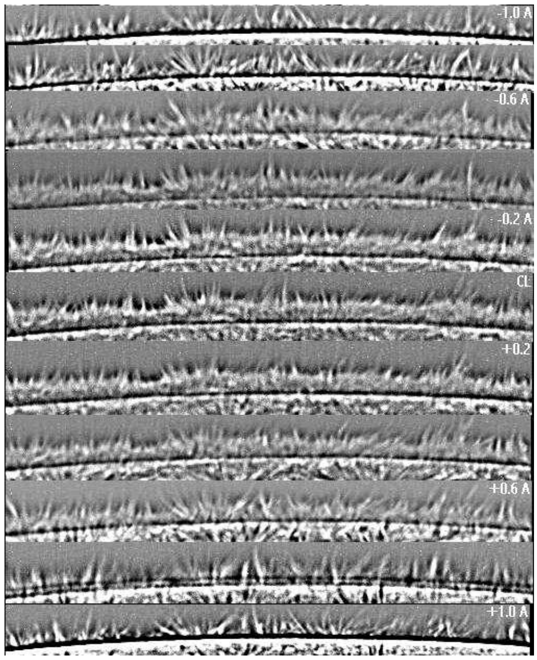

Fig. 24: A series of images displaying spicules in Hα on the solar limb. These images are displayed through the courtesy of the Big Bear Solar Observatory which have described the series as follows, *Limb Spicules: The Figure shows the limb of the Sun at different wavelengths within the H-alpha spectral line (from 0.1 nm bluewards to 0.1 nm redwards of the line center). Some of the spicules (jets) extend above height of 7000 km. The images have been processed with a high pass filter.*" http://www.bbso. njit. edu/ images.html — Accessed on 9/30/2013.

Spicules seem to move up with nearly uniform speeds [206, p. 61]. These speeds can actually increase with elevation [150, p. 45–60]. Spicules can rise in jerky fashion or stop quite suddenly [150, p. 45–60]. They can *"expand laterally or split into two or more strands after being ejected"* [337].

All of this behavior, and the ability to document it, suggests that spicules are not devoid of density against an even sparser background. Rather, they seem to be the product of condensation. It is almost as if much of the material in the chromosphere exists in a state of critical opalescence, that strange state wherein matter is not quite liquid and not fully gaseous [35].§ Just a slight disturbance can cause the entire substance to rapidly condense. Such a process would be essentially independent of direction (vertical or horizontal), but

*This proof was first presented as the seventh line of evidence [35, 56, 59, 61].

†Spicules extend well into the lower corona where densities, according to the gaseous models, could be no greater than ~10^{-15} g/cm^3, i.e. the density of the upper chromosphere [148]. The associated densities are ~10^{-12} of the Earth's atmospheric density at sea level (~$1.2\text{x}10^{-3}$ g/cm^3 [149]).

‡Some authors have attempted, although not very convincingly, to establish a relationship between spicular velocities and gravitational forces (e.g. [337]).

§The author has previously described the situation as follows, *"Critical opalescence occurs when a material is placed at the critical point, that combination of temperature, pressure, magnetic field, and gravity wherein the gas/liquid interface disappears. At the critical point, a transparent liquid becomes cloudy due to light scattering, hence the term critical opalescence. The gas is regaining order as it prepares to re-enter the condensed phase"* [35].

would be guided by local fluctuations in material concentrations. This would explain the erratic behavior and orientation of spicules.

The formation of spicular material suggests processes that are being observed near the critical point of a dense form of hydrogen [92] in the chromosphere. In moving from the corona to the photosphere, the effect of gravity becomes more important and, though temperatures might not be changing much (see §2.3.7), material in the chromosphere could be falling sufficiently below the critical point to allow for rapid condensation [35].*

Whether or not critical phenomena are being expressed in the chromosphere [35], it remains relatively certain that spicules themselves represent sites of condensation in the solar atmosphere, as manifested both by their dynamic behavior and by the emission lines with which they are associated (§3.4, §3.5, §3.6 and [59, 61]). It is highly likely that spicules are not propelling matter into the corona, but rather, that they are enabling hydrogen, present in the solar atmosphere, to reassume a condensed state and return to the solar body. In this case, they act to harvest hydrogen and return it to the photospheric intergranular lanes [59], as illustrated above in Fig. 14.

As with coronal rain, the chromospheric matter which makes up spicules should be comprised of dense hydrogen which is non-metallic, as it retains some hydrogen-hydrogen molecular interactions within its lattice [92]. This dense form of hydrogen, upon entering the pressurized environment of the solar interior, could then be transformed back to the metallic state [59].

5.7 Splashdown Events #31

Following violent flares, matter can be seen falling, in large fragments, back onto the solar surface.† The phenomenon resembles a huge mass of liquid projected into the air and then crashing back to the ground. A particularly impressive event was witnessed on June 7, 2011 [340, 341]. Solar material was ejected, as a great, almost volcanic appearing event, occurred on the photosphere. Solar matter was projected far into the corona, reaching heights well in excess of 500,000 km. Upon reaching a certain impressive altitude, the ejected photospheric matter was seen to fall back onto the solar body. Striking the surface, the descending material produced strong brightening at the impact points.

These events elegantly support the contention that flares and CMEs are driven by the buildup of pressure within the solar interior, not by transferring energy from the corona [189]. Most importantly, following the ejection of material from a flare, the return of mass towards the solar surface can be distinctly visualized. The associated impact points provide clear evidence that the ejected material and the surface upon which it splashes are comprised of condensed matter.

5.8 Solar Winds and the Solar Cycle #32

Solar winds have presented astronomy with a wealth of information, especially when addressing variations in helium abundances [342–351].‡ Two kinds of solar winds can be monitored. They are known as slow (<400 km/s) and fast (400–800 km/s) winds [349]. They differ only slightly in their particles fluxes (2.7×10^8 cm^{-2} s^{-1} versus 1.9×10^8 cm^{-2} s^{-1}, respectively), though they can have significant variations in their proton densities (8.3 cm^{-3} versus 2.5 cm^{-3}, respectively) [349]. Fast solar winds are typically associated with coronal holes [52, 349].

For the gaseous solar models, the origin of solar winds depends on the presence of a hot corona, which thermally expands as gravitational forces decrease with distance [352]. The body of the Sun is not involved, as a gaseous Sun must remain in perfect hydrostatic equilibrium, i.e. the forces of gravity must be exactly balanced with electron gas and radiation pressure [13, p. 6–7].

In bringing forth a solution for the origin of solar winds, Parker [352] would carefully consider earlier findings [353, 354]. Biermann had studied the orientation of comet tails and concluded that coronal particles were flowing away from the solar body [353]. At the same time, Unsöld and Chapman deduced that the Sun was expelling charged particles responsible for geomagnetic storms and computed the associated densities [354]. Parker would make the logical link between these events, but required for his solution that the space occupied by coronal matter expanded as it moved away from the Sun [352]. In order to permit this expansion, he postulated that the corona must exist at millions of degrees [352]. He believed that the outer corona could remain very hot, since Chapman had calculated, a few years before [355], that ionized gases could possess tremendous conductivities. Therefore, heat could be channeled from the lower corona to the outer solar atmosphere, to drive the solar winds.

As a result, the gaseous models have required the impossible from the corona. The latter must be heated to temperatures well beyond those of the solar core (see §3.8) using processes based on magnetic fields [148, p. 239–251]. Then, it must transfer this energy in two directions. First, the corona must be able to drive all violent activity on the solar surface [12], like flares and coronal mass ejections (see §5.1 and [179]). Second, it must allow energy, through its elevated conductivity [355], to reach the outermost layers of the solar atmosphere. In this manner, the corona itself can provide the thermal energy required to drive the solar winds [352].

But, if energy can dissipate into the outer corona through elevated conductivity, how can it be available to drive surface activity? How does the directionally opposite flow of heat in a

*There could be substantial opposition to the idea that critical phenomena are being observed in the chromosphere. However, spicule formation seems to reflect the scale length effects which characterize these processes.

†This proof was first presented as the 24th line of evidence [53].

‡This proof was first presented in [47, 48, 52].

conductive material, like the corona, not constitute a violation of the Second Law of Thermodynamics?* Furthermore, why require that heat be transferred into the corona from the solar interior prior to its application elsewhere in the Sun? Why not simply let the solar body do the work?

In any event, to maintain the requirements of hydrostatic equilibrium [13, p. 6–7], the Sun must let its ultra-low density vacuum-like corona maintain every unexplained process. It does so by transferring energy from the solar interior using magnetic fields, even though gases are unable to generate such phenomena §5.3.

The requirements that the corona is hot also introduces the problem of the cool K-coronal spectrum (see §2.3.7), which must, in turn, be explained with relativistic electrons. How could relativistic electrons survive in a conductive medium? Resorting to this proposal hampers the search for the underlying causes of the solar cycle.

Conversely, Christophe Robitaille has theorized that the Sun is expelling non-hydrogen elements synthesized within its interior (private communication and [48]).† In the LMH model, the Sun possesses a true graphite-like layered lattice (see Fig. 2) over much of its volume, except perhaps, in the core.‡ It is known in graphite, that layered lattices can accommodate the intercalation of atoms [18], as has been illustrated in Fig. 19. In this case, protons occupy the hexagonal planes, electrons are flowing in conduction bands, and non-hydrogen atoms are found in the intercalation regions. These atoms can freely diffuse in the intercalation zones, but would experience restricted diffusion across hexagonal hydrogen planes (see Fig. 19). Such simple considerations, within the context of intercalate structures, can readily account for the solar winds [47, 48, 52].

In this model, the tremendous pressures within the solar interior provide the driving forces for the solar wind. Non-hydrogen atoms in intercalation regions are being expelled from the solar body by simple mechanical action, in accordance with known exfoliative processes in graphite [48]. For instance, an atom traveling at 800 km/s could leave the center of the Sun and escape at the surface in only fifteen minutes [52].§

During quiet solar periods, the known presence of fast solar winds over coronal holes [52, 349] could be readily explained. It requires that the intraplanar axis (A in Fig. 2) of metallic hydrogen, in the polar convection zone, be positioned orthogonally to the solar surface [52]. This would enable the rapid ejection of intercalate atoms from the solar interior at the poles when the Sun is quiet.¶ In the convection zone below the solar equator, the intraplanar axis (A in Fig. 2) would be rotated by 90°, becoming parallel to the solar surface. This would act to restrict the degassing of intercalate atoms, resulting in slow solar winds above the equator.

A clearer understanding of solar winds provides new insight into helium abundances [47]. It has been argued that current estimates of solar helium levels are largely overestimated [47]. Evidence suggests that, during active periods, the Sun is expelling helium from its equatorial region, not retaining it (see Fig. 15) [47].

Helium levels in the solar wind can vary substantially with activity. When the Sun is quiet, the average He/H ratio in the slow solar wind is much less than 2%, often approaching <0.5 % (see Fig. 1 in [348]). However, when the Sun is active, the ratio approaches 4.5% [348]. Relative helium abundances can rise substantially with solar activity, like flares [347], and the He/H ratio increases dramatically during geomagnetic storms [343]. Extremely low He/H ratio values of 0.01, rising to 0.08, with an average of 0.037 have been reported, when the Sun was quiet [343]. He/H ratios can vary greatly, especially in slow solar winds [343, 346]. Therefore, astronomers have assumed that solar winds cannot be used to assay this element [347]. However, it is more likely that what is being observed has not been correctly interpreted.

Extremely low He/H ratios challenge the premise that the Sun has an elevated helium abundance [47, 241, 242], sending shock waves throughout cosmology (see [47] for more detail). As helium can be essentially absent from the solar wind, astronomers, rather than infer that the Sun has a low helium abundance, assume that the elements must not be properly sampled. Helium must be gravitationally settling in the Sun (see [48] for a detailed discussion) or is being destroyed on the way to the detectors by processes occurring in the corona [347, p. 298].

The fast solar wind is thought to represent a less biased appraisal of elemental abundances [347, p.295], precisely because helium is being ejected from the Sun and subsequently appears abundant. Aellig et al. report that the fast solar wind has a helium abundance of 4–5% throughout the course of their five year observation (see Fig. 2 in [348]).

These results can be readily explained when considering that the Sun is condensed matter. When the Sun is quiet, it is degassing its intercalation regions, primarily from the poles. Large amounts of helium can accordingly populate the fast solar wind. When solar activity is initiated, the Sun begins to degas its equatorial regions. Much of this helium then travels along with slow solar winds to our detectors, and those concentrations are likewise elevated. However, when the Sun is

*It is already difficult to accept that a low density vacuum could transfer its energy to the solar surface. This scheme becomes even more strained when coronal energy is permitted to flow freely, using conductive paths, away from the Sun. The only solution implies a violation of the First Law of Thermodynamics, i.e. energy is being created in the middle of the corona.

†Lithium provides one notable exception, as seen in §3.3 and [54].

‡A body center cubic structure, as proposed in computational studies of dense plasmas by Setsuo Ichimaru [97], would be appropriate for the solar core (see §6.5).

§This compares to thousands, perhaps millions, of years for a photon to leave the core of the gaseous Sun (see §2.3.1 and [42]).

¶Coronal holes persist above the poles during periods of reduced solar activity (see §4.6).

quiet, virtually no helium reaches our detectors in the slow solar winds, as this element is now trapped in the equatorial intercalation regions. This scenario provides strong motivation for concluding that the Sun is actively degassing helium and that the true internal abundances of this element must be much lower than currently estimated [47, 241, 242].*

Not only can the LMH model account for the production of solar winds, but it advances an underlying cause of the solar cycle: degassing of the solar body [48, 52]. When the Sun is quiet, fast solar winds are able to degas the convection zones below the poles. This helps to explain why sunspots are never seen at these latitudes. However, during this period, the equatorial regions are experiencing restricted degassing. This is due to the parallel orientation of the hexagonal hydrogen planes in layered metallic hydrogen lattice, with respect to the solar surface. Such an orientation prevails in the underlying convection zone when the Sun is quiet. Solar activity is initiated when active degassing of the equatorial planes begins. This occurs in association with a rotation or partial breakdown of the hydrogen planes, as was seen when discussing sunspots (§2.3.3). This is the reason why coronal holes can appear anywhere on the solar surface when the Sun is active, as discussed in §4.6. When accounting for solar winds, coronal holes, and solar activity, the LMH model far surpasses in insight anything offered by the gaseous models.

6 Helioseismic Lines of Evidence

Seismology remains a science of the condensed state. Even so, proponents of the gaseous models adhere to the belief that helioseismology can claim otherwise. In this section, a group of six helioseismic conclusions will be briefly examined. Each provides compelling evidence that the Sun is comprised of condensed matter. It might be argued that other helioseismic lines of evidence could be extracted. Only six have been selected for their scientific impact.

6.1 Solar Body Oscillations #33

The Sun acts as a resonant cavity.† It sustains oscillations, as sound waves travel (see Fig. 25), within its interior [356–360]. The most prevalent solar oscillation has a period of 5 minutes, but many more modes exist [356–360]. Thus, the solar surface is reflecting internal audio waves and this causes the entire solar body to *'ring'*, as it succumbs to seismic activity.

Though scientists currently utilize helioseismology to justify the gaseous models [356–360], the conclusions would be better suited to a condensed Sun. It is not reasonable that a photosphere, with a density of only ~10^{-7} g/cm^3 [148], can act as a resonant cavity. Within the gaseous models, the Sun has no distinct surface, hence it cannot provide a physical boundary to sustain solar oscillations.

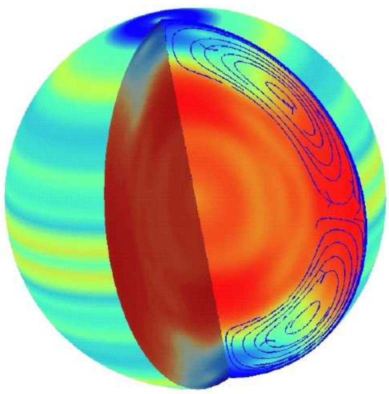

Fig. 25: Variations in sound speed within the Sun. Red regions are hotter than the standard solar models, while blue regions are cooler. This image has been provided courtesy of SOHO/[Michelson Doppler Imager] consortium. SOHO is a project of international cooperation between ESA and NASA. (http://sohowww.nascom.nasa.gov/gallery/images/mdi025.html — Accessed on 10/1/2013).

Fig. 25 displays slight differences in sound speed with the standard gaseous model. A detailed analysis of such studies can be profitable. Bahcall et al. [361] have also compared theoretical results with experimental helioseismic findings for standard gaseous models. Absolutely amazing fits are obtained throughout the solar interior, but the authors fail to provide comparisons for the outer 5% of the Sun (see Figs. 12 and 13 in [361]). Yet, all observational data is being acquired precisely from this region. Therefore, any perceived experimental/theoretical agreement has little validity.

As was concluded in §3.1, the Sun presents the observer with a distinct surface in the UV and X-Ray bands. This surface is covered by low-frequency 3 mHz oscillations [362]. Evidence for a distinct surface has also been presented by gamma-ray flares (see §3.2). The Sun behaves as a resonant cavity in the audio bands, implying a true surface. But the gaseous models must maintain that the solar surface is but an *'illusion'*, to somewhat poorly account for limb darkening (see §2.3.2). Unfortunately, illusions make for poor resonant cavities. It is more logical to infer that the Sun has a distinct surface over the entire span of relevant wavelengths (audio to X-ray), as provided by condensed matter.

Despite denial that the Sun is either liquid or solid, astronomers refer to solar seismic events as *"similar to earthquakes"* [362]. Such analogies are in keeping with the known truth that seismology is a science of condensed matter. The same can be said for the Sun.

*In this regard, it should be remembered that the chromosphere and the corona are working to actively recapture hydrogen, protons, and electrons. This would act to elevate the He/H ratio detected in any solar wind. In addition, since the Sun is degassing intercalate regions and its average stage index (see Fig. 19) may be quite large, the solar body might best be viewed as composed almost entirely of hydrogen.

†This proof was first presented as the fifth line of evidence [35, 36, 42].

6.2 Mass displacement #34

On July 9, 1996 a powerful X-ray flare disrupted the solar surface, as illustrated in Fig. 26 [362, 363].* This image was obtained through Doppler methods. Consequently, material moving towards the observer appeared brighter, while matter propagating away from the detector seemed darker. Therefore, the flare itself was bright.

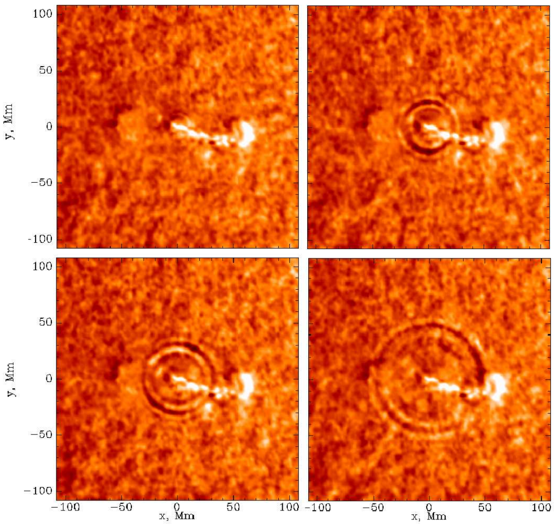

Fig. 26: Doppler image of a solar flare and the associated disturbance on the solar surface acquired by the NASA/ESA SOHO satellite [362]. Courtesy of SOHO/[Michelson Doppler Imager] consortium. SOHO is a project of international cooperation between ESA and NASA.

Kosovichev and Zharkova [362] support the notion, central to the gaseous models, that flares are being excited with coronal energy. They suggest that *"a high-energy electron beam* (is) *heating the cool chromospheric 'target' "*. Surface activity is driven, not from the interior of the Sun, but from the coronal vacuum. Nonetheless, the displacement of material observed in Fig. 25 strongly supports Zöllner's ideas regarding the nature of solar flares, as previously discussed in §5.1 and §5.7. It appears that the flare was produced when pressurized material was ejected from the solar body beyond the photospheric surface.

But, when the flare emerged, it produced enormous transverse waves on the surface of the Sun. The crest to crest distances are on the order of 10 Mm. Kosovichev and Zharkova [362] describe these transverse waves as *"resembling ripples from a pebble, thrown into a pond"* and maintain that the behavior can be explained with computations involving gas models. Still, they visualize *"ripples on a pond"*, a direct reference to behavior which can only be observed in condensed matter. Gases can sustain longitudinal, not transverse waves. Attempts to generate these waves, not only in a gas, but in an ultra-low-density vacuum, challenges scientific reason.

6.3 Higher Order Shape #35

Seismological studies have revealed that the Sun is not perfectly oblate (§4.4) but rather, is characterized by higher order quadrupolar and hexadecapolar shape terms which appear dependent on the solar cycle [364].† Higher order shape terms involve forces beyond those produced with simple rotation of a homogeneous liquid mass. They imply *internal structure within the Sun*. Hence, they stand as a sublime indication that the solar body possesses real structure beyond the core.

It would be extremely difficult to justify that fully gaseous objects could ever sustain observable internal structural effects. Yet, the higher order quadrupolar and hexadecapolar shape terms must arise from internal structure. Conversely, within the context of the LMH model, higher order shape terms would be expected. It has already been mentioned that the hexagonal hydrogen plane orientation (see Fig. 19), at the level of the convection zone, could account for coronal holes, solar winds, and the solar cycle (see §5.8). Hexagonal hydrogen planes could give rise to large layers, moving over one another, whose orientation relative to the solar surface could slowly vary from equatorial to polar regions (i.e. parallel versus orthogonal).‡ This would give rise to true underlying structure in the convection zone, as expressed in higher order shape terms.

6.4 Tachocline and Convective Zones #36

The Sun possesses a convection zone characterized by differential rotation [356–360].§ While a gas can easily be thought to undergo differential rotation, the Sun is characterized by another region: a tachocline layer separates the convection zone from the solid solar core (see §6.5).

The tachocline region acts as a shear layer within the Sun. This layer is known to be prolate in nature [360, 365–367]. The tachocline is generally thicker and shallower at the higher latitudes [360, 366]. It seems to display some temporal variability across the solar cycle [366], strongly suggesting, once again, that structural changes are taking place within the solar body (see §5.8 and §6.3).

When considering the tachocline layer, it is important to recall that shear stresses require the presence of a physical plane. For instance, the equation for shear stress, τ, states that τ=F/A, where F=force and A=Area. It is not possible

*This proof was one of the earliest [4, 29] and was presented, at one time, as the sixth line of evidence [35].

†This proof was first presented in [50], as supportive of §4.4. However, solar oblateness does not depend on the use of helioseismology for its determination (§4.4) and has been invoked by Jeans [27, 28] as providing a mechanism to generate binaries [3]. As for higher order shape, it is indicative of forces which differ from those involved in creating oblateness. Upon reconsideration, higher order shape now stands on its own as a separate line of evidence.

‡This resembles tectonic shifts on Earth. Such a parallel was drawn by Luc Robitaille (personal communication).

§This proof was first presented as the nineteenth line of evidence [50].

to have a shear stress without acting on a surface, or an organized lattice plane of atoms, as provided by condensed matter. Imaginary planes cannot experience shear forces.

Consequently, the shear nature of the tachocline, and the fact that it displays a prolate nature, provides clear evidence that the solar body is physically structured. Furthermore, it appears that this is an area of the Sun which can undergo changes with the solar cycle. These results are most gracefully explained by the LMH model.

6.5 Solar Core #37

As was suggested in §6.4, the core of the Sun undergoes solid body rotation [368].* This conclusion, has been reached by a virtual *who's who* of authority in helioseismology [368]. In the central portion of the Sun, *"... the rotation rate appears to be very little, if at all. Its value is 430 nHz"* [368].

Solid body rotation in the solar interior directly implies that the body of the Sun cannot be gaseous. This rotation requires the presence of powerful cohesive forces within the Sun. None can exist in a gaseous object.

The observation is more in line with Setsuo Ichimaru's conjecture (§2.3.1 and §5.8) that the central portion of the Sun can be considered to exist as a one-component plasma of metallic hydrogen [97, pp. 103 & 209]. Ichimaru adopted the body-centered cubic structure in his studies [97–99] and this lattice configuration would make sense at the center of the Sun.

In this respect, Ichimaru based the density of metallic hydrogen in the core on conclusions derived from gaseous models. If the photosphere of the Sun is truly condensed, then the values he adopted (56.2 g/cm^3 [98, p. 2660]) would be much too elevated. In a liquid model, the density cannot vary much throughout the solar body, remaining near 1.4 g/cm^3 (i.e. slightly lower at the photosphere and slightly higher in the core). At the center of the Sun, we are merely witnessing a change in lattice structure from a layered Type-I lattice over most of the photosphere, to a more metallic layered Type II lattice in the convection zone, and finally to a body-centered cubic lattice in the core. Intercalate atoms would be present within Type I and Type II layered lattices. If they change from the condensed to the gaseous phase, these intercalate atoms could slightly reduce the average densities of these layers.

The LMH model is more in keeping with physical observations within the Sun. It is not reasonable to advance that gases rotate as solid bodies. Condensed matter enables the formation of a solid core which can account for the observed rotations.

6.6 Atmospheric Seismology #38

Helioseismology has been extended to the outer solar atmosphere [214, 369–372].† Coronal and chromospheric studies [214, 369–372] have successfully detected seismic waves in this region of the Sun and the presence of both incompressible and compressible waves is now well-established. These are viewed as magnetohydrodynamic waves (MHD) in nature.‡

The existence of incompressible transverse waves in the solar atmosphere [214, 369–372] suggests, once again, that this region of the Sun contains condensed matter. These have been observed in spicules [214] and within the chromospheric level [372]. Their detection implies that the densities of these solar layers are well in excess of those which typify Earthly vacuums.

As a point of interest, it is known that comets can send shock waves throughout the solar corona and chromosphere. On January 29, 2013 (see [373]), a comet begins to disrupt the solar atmosphere when it is more than 1R$_\odot$ away from the solar surface. At this location, the corona has no density (<10^{-15} g/cm^3, the density of the upper chromosphere [148]), according to the gaseous models. It is unfeasible that an ultra-low-pressure vacuum could be able to respond to the entry of a comet in this manner. The ability of comets to trigger shock wave propagation throughout the solar atmosphere indicates that this is a region of elevated density. This conclusion is in keeping with the LMH model of the Sun.

7 Elemental Lines of Evidence

7.1 Nucleosynthesis #39

It has been gloriously stated that the elements were formed in the stars.§ In this, there appears to be much truth [374–388]. From its inception, stellar nucleosynthesis has always been closely linked to stellar evolution [129, 374–378].

The idea that the Sun could synthesize helium was first proposed by men such as Gamow [377, 378], Bethe [379–381], von Weisäcker [382] and Hoyle [383, 384]. The p-p reaction, wherein two protons combine to make a deuteron, while relying on positron and neutrino emission, would come to play a vital role in ^{4}He synthesis within low mass stars [374, p. 118]. For stars with a greater mass than the Sun, Bethe and von Weisäcker, in 1938 and 1939 [380–382], advanced that ^{4}He was being formed in a simple cycle involving nitrogen, carbon, and oxygen (CNO).

Early on, Hans Bethe had argued that *"no element heavier than ^{4}He can be built up in ordinary stars"* [381]. With those words, the Sun was crippled and stripped of its ability to make any element beyond helium.

Bethe had reached his conclusion based on the probability of nuclear reactions in the gas phase and at the temperatures of ordinary stellar cores [381, p. 435]. If this was true, how did the Sun come to acquire the other elements? For Bethe, the answer appeared straightforward, *"The heavier elements found in stars must therefore have existed already when the*

*This proof was first presented as the twentieth line of evidence [50].

†This proof was first presented as the 29th line of evidence [58].

‡See [372] for a brief, but well compiled, literature review.

§This proof was first presented in [44, 48].

star was formed" [381]. Extremely large and hot, first generation stars, had, soon after the Big Bang, created the heavy elements [389]. These elements merely represented contamination in the Sun, a product of objects extinguished long ago.

At the time that the CNO cycle was outlined [380–382], the discovery of metabolic cycles was creating a fury in biology. Just a few years before, in 1932, Hans Krebs (Nobel Prize, Medicine and Physiology, 1953) had discovered the urea cycle [390]. He would go on to outline the tricarboxylic acid (TCA or Krebs) cycle in 1937 [391], the discovery for which he gained international acclaim. It cannot be doubted that these great pathways in biology influenced astrophysical thought. Cycles seemed all powerful.

Biological cycles initially concealed their many lessons. It would take years to fully understand that they were highly regulated entities. Biological cycles required a complement of reactions and cofactors (small activator molecules or ions) which could either sustain the levels of intermediates or activate key enzymatic reactions. Similar regulation would be difficult to envision in the case of the CNO cycle. As a result, can this cycle truly occupy central positions in the synthesis of ^{4}He in the stars? Why confound the process by resorting to a cycle, when simple reactions between hydrogen atoms should be sufficient for all stars?

It would seem fortuitous that precisely the proper amounts of carbon, nitrogen, and oxygen has been distributed within stellar interiors, to permit these reactions to take place. If stars are truly gaseous, how do they ensure that these elements are not destroyed, or used up, by competing nuclear reactions — something which can be prevented or exploited to advantage in biology? Unlike a biological cell, with its intricate means of forming, separating, and transferring metabolites, the gaseous star cannot control the course of a single reaction. Everything must occur by chance. This complication is directly opposed to the subsistence of cycles.*

Concerning nucleosynthesis, proponents of the gaseous models require the improbable. Hobbled by theory, they must claim that first generation stars created the heavy elements. Moreover, they advance that, while mankind has successfully synthesized many elements, the Sun is unable to build anything beyond helium. First generation stars which no longer exist had done all the work [389]. These conclusions, once again, call for the suspension of disbelief. It is much more reasonable to assume that the Sun has the ability to synthesize all the naturally occurring elements, based on their presence in the solar atmosphere.

In turning his attention to dense plasmas, Ichimaru recognized that they could provide additional freedom in elemental synthesis [97–99]. These ideas have merit. In the LMH model, dense structures enable the synthesis of heavy elements which is not restricted to the solar core, but expressed in the convection zone where the intercalation regions can be found.

A metallic hydrogen framework can restrict protons to lattice points in the hexagonal plane and confine other atoms to the intercalate layer [48]. Solar pressure and lattice vibrations could act in concert to enhance the probability of nuclear reactions. Two adjacent protons, in the hexagonal hydrogen plane, could give rise to a deuterium atom, with the associated positron and neutrino emission [388]. This deuterium could then react with another, leading directly to the synthesis of ^{4}He. Alternatively, it could fuse with a proton, leading to the formation of ^{3}He. Both ^{4}He and the light helium isotope, ^{3}He, would be immediately ejected into the intercalation region [48].† Over time, the intercalation region could sustain other nuclear reactions and become the birthplace of all naturally occurring heavy isotopes. The Sun and the stars gain the ability to synthesize all of the elements [44, 48].

In this regard, it is well-known that solar flares can give tremendous ^{3}He abundance enhancements [180]. Eruptive flares have been known to produce ^{3}He/^{4}He ratios approaching 1 [186], and thousand-fold enhancements of this ratio have been observed [392]. These findings can be better understood in a solar model wherein ^{3}He is being preferably channeled into intercalation regions over ^{4}He. ^{3}He could then display an enhancement over ^{4}He when released into the solar atmosphere during activity.‡ It would be difficult to account for the finding for the gaseous models, but the result can be reasonably explained using the LMH model.§

8 Earthly Lines of Evidence

The earthly lines of evidence may be the most powerful. They are certainly the most far reaching. Climate dictates our future and the survival of humanity.

Thus, it is fitting to close this discussion with the climatic line of evidence. This acts to highlight that there is much more to studying the Sun than intellectual curiosity. As such, the *'Young Sun Problem'* and the great Maunder minimum of the middle ages are briefly discussed.¶

*Note that the author has proposed a cycle in §3.6. In this case however, the formation of triplet He has not been left to chance. It is the direct product of a systematic chemical reaction. The other reactant in the cycle, hydrogen, is present in excess.

†^{3}He could also emit a positron to make tritium, ^{3}H. Remaining in the hexagonal plane, this hydrogen isotope could then react with a single proton to make ^{4}He, which could then be expelled into the intercalate region.

‡This requires simply that the reaction of a deuterium atom with a proton is preferred over its reaction with another deuterium atom. This would be expected in a hyrogen based Sun.

§The solar neutrino problem has not been addressed in this work as a full exposition would involve too much discussion. Suffice it to state that difficulties involved in obtaining proper neutrino counts highly suggest that the Sun is sustaining other nuclear reactions beyond the simple synthesis of ^{4}He.

¶These constitute a single line of evidence as they are both related to climatic changes on Earth.

8.1 Climatic #40

8.1.1 The Young Sun Problem

The gaseous models infer that, when the Sun was young, it was much cooler than it is at present [393–395]. Once thought to be faint and dissipating much less heat onto the surface of the Earth, a gaseous Sun became increasingly warm over time. Thus, the Sun was once thought to be faint, dissipating little energy onto the Earth. Two billion years ago, the mean temperature of the Earth's surface would have been below the freezing point of water [393]. A paradox arises, since geological studies have revealed that water existed on Earth in liquid state as early as 3.8 billion years ago [393–395].

In order to resolve this problem, Carl Sagan was one of the first to advance that the answer could be found in the Earth's atmosphere [395]. If the young atmosphere was rich in CO_2, then the greenhouse effect and global warming [396] provided an explanation [393–395]. Everything appeared to be resolved [393].

Still, some remained unsatisfied with the greenhouse solution. Several stated that a young Sun was more massive and accordingly, hotter [393, p. 457]. In this scenario our Sun lost enormous amounts of material over the years through *"a vigourous, pulsation driven, solar wind"* [393, p. 457]. The young Sun could have been fifteen times more luminous than now, simply as a consequence of these changes in mass [393, p. 458].

But, it is difficult to conceive how a gaseous star, violently expelling mass despite great gravity, will cease to do so as gravitational forces decrease. Nonetheless, these basic ideas have survived, although with less dramatic changes in mass loss [397]. In this approach, the gaseous young Sun was not faint, but bright [397]. This was more in keeping with warm temperatures both on the Earth and on Mars [397]. Greenhouse effects could not simultaneously explain these findings.

In the end, the LMH model has a distinct advantage relative to the young Sun problem. Only the gaseous equations of state demand that a star like the Sun must become increasingly luminous as it evolves.* But over time, a Sun based on condensed matter, should cool from the most luminous (Class O) to the coolest star type (i.e. Class M).

Some may highlight that, if our Sun was once an O class star, there should be no water on Earth. The supposition is not valid. When the Earth was young, scientific consensus states that it was molten (see e.g. [399]). This can be easily explained if the Sun was once an O Class star, but not if it was a faint gaseous object. The Earth, like our Sun, cooled over time. The LMH model is much more in accordance with observational facts in this regard.†

8.1.2 The Maunder Minimum

A great minimum appeared in the Sunspot cycle during the middle ages. This minimum was first recognized by Spörer and Maunder [400–404]. It is known today as the *Maunder minimum* [403]. Many believe that the Maunder minimum was associated with a *'little ice age'* on Earth [403]. The conclusion is particularly timely, since the Sun may be entering another minimum in 2013, as solar activity apparently drops to a 100 year low [405].

What causes these minimae? In gaseous models, the answers will be difficult to ascertain, as these ideas have difficulty accounting for any solar activity. As for the LMH model, it is based on the tenant that solar activity must be fundamentally related to degassing of intercalate atoms. Perhaps the Maunder minimum arises because the Sun has been thoroughly degassed, either through an unknown internal mechanism or an external force.

In this regard, it may be important to recall that comets appear to send shock waves through the solar atmosphere as they come near the Sun [373]. These shock waves could be degassing our star beyond normal, hence reducing the need for future solar activity. *Shock degassing* may seem unlikely. However, comets do have periodic motions around the Sun. One or more could cyclically return to cause such effects. In this respect, the comet ISON is arriving in just a few days [406]. It will be interesting to note the shock wave it commands as it orbits the Sun.‡

8.2 Conclusion

Throughout these pages, a trial has unfolded relative to the constitution of the Sun. Prudent consideration of the question requires the objective analysis of solar data. Observations must be gathered and rigorously considered in light of known laboratory findings. Such were the lessons imparted long ago when Gustav Kirchhoff first contemplated the nature of the Sun [26].

Kirchhoff's approach has now been repeated. A wealth of information has been categorized and meticulously evaluated. Data spanning every aspect of the solar science has been included. Not a single fact was deliberately omitted or ignored. Rather, the full complement of available evidence has been weighed and described. The Sun itself was permitted to offer full testimony. In completing this exercise, a total

*The author has previously addressed Lane's law and the increased luminosity gained by the gaseous stars as they evolve [3]. With respect to stellar evolution, the LMH model will advance that stars cool as they evolve and do not increase in luminosity. The brightest stars (Classes O and A) are actually the youngest, while the faintest are the oldest (Class M). This is completely contrary to current beliefs in astronomy. Stellar evolution will be addressed in considerable in detail in an upcoming work [398].

†The mystery of the appearance of water on a planet that was once molten has not been properly addressed by anyone to the author's knowledge.

‡Shock related degassing of the Sun should be viewed as something positive. A star unable to properly degas might well exfoliate, as discussed in [48], and become a red giant or a supernova. Therefore, shock degassing may well be necessary, even if Earthly temperatures subsequently fall for rather long periods of time.

of forty lines of evidence have been addressed in seven broad categories. Each has spoken in favor of condensed matter.

Of these, the Planckian lines of evidence, as outlined in §2, will always merit the preeminent positions, since they directly reveal true lattice structure at the atomic level. The solar spectrum, limb darkening, and the directional emissivity of many structures (sunspots, granules, faculae, magnetic bright points, spicules, the K-corona, and coronal structures) highlight that metallic and non-metallic material can be found within the Sun.

The spectroscopic lines of evidence may well be the most elegant. It is not only that they provide obvious clues for a solar surface, but that they finally expose the underlying cause of line emission within the chromosphere and corona. In this regard, molecular hydrogen and the metal hydrides strongly suggest that the chromospheric flash spectrum reflects the presence of condensation reactions in the solar atmosphere. Yet, it is triplet helium which has rendered the most definitive declaration. It appears that an activated helium cycle does indeed exist in the chromosphere, harvesting hydrogen atoms and enabling them to rejoin the solar surface. In concert, the cool-LMH-containing K-corona scavenges electrons, thus helping to preserve solar neutrality. The associated light emission from highly ionized ions speaks to the power of spectroscopic observation.

The structural lines of evidence remain the simplest to understand. The many arguments concerning solar collapse, density, dimension, shape, appearance, and extent, are simultaneously straightforward and disarming.

Perhaps the most intriguing lines of evidence are dynamic manifestations of solar activity. Surface activity, the boiling action of the Sun, and the orthogonal arrangement of its photospheric/coronal flows leave no opportunity for a gaseous Sun. The existence of a solar dynamo, with its requirement for the interplay between conductors and insulators, offers no more. Coronal rain and loops, along with spicular velocities and splashdown events, require the presence of condensed matter. Slow and fast solar winds point to an object constantly striving to expel material, emphasizing the dynamic aspects of a condensed Sun.

Few sciences are more tied to condensed matter than seismology. The Sun with its oscillations, mass displacements, shape, internal layers (convection zone, tachocline, and core), and atmospheric waves, has highlighted that it belongs in the company of solids and liquids.

Elemental lines of evidence call for a complete revision of scientific thought relative to how the Sun derives its energy. First generation stars must join the company of other untenable theories, as an unchained Sun is finally permitted to synthesize all of the elements.

The sole earthly line of evidence was climatic. In ages past, the Earth was molten. The Sun must have been much more luminous than it is today, leading to the conclusion that it was born as an O-class star. Its temporal variations across the ages, might be best understood as an ever-present need to eject elements from its interior.

Finally, a conclusion must inevitably be drawn. Can a gaseous Sun truly survive, based solely on mathematical arguments, when not a single observational line of evidence lends it support? In the end, such an arsenal of observational proofs has been supplied that there can be little doubt in the answer. Formulas can never supersede observational findings. Hence, only a single verdict can be logically rendered. The Sun must be comprised of condensed matter.

The consequences are far reaching. They call for a new beginning in astronomy. Nonetheless, there is hope that a reformulation of astrophysics can bring with it a wealth of knowledge and discovery. As scientists turn their thoughts to a condensed Sun, may they renew their fervor in the pursuit and understanding of stellar observations.

Epilogue

No more appropriate closing words can be uttered than those of Cecilia Payne, she who established that we live in a hydrogen based universe [86]: *"The future of a subject is the product of its past, and the hopes of astrophysics should be implicit in what the science has already achieved. Astrophysics is a young science, however, and is still, to some extent, in a position of choosing its route; it is very much to be desired that present effort should be so directed that the chosen path may lead in a permanently productive direction. The direction in which progress lies will depend on the material available, on the development of theory, and on the trend of thought . . . The future progress of theory is a harder subject for prediction, than the future progress of observation. But one thing is certain: observation must make the way for theory, and only if it does can the science have its greatest productivity . . . There is hope that the high promise of astrophysics may be brought to fruition."* Cecilia Payne-Gaposchkin [407, p. 199–201].

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*Agency URLs — http://www.isf.astro.su.se; http://sdo.gsfc.nasa.gov; http://sohowww.nascom.nasa.gov; http://www.bbso.njit.edu.

Not enough can be said of Dmitri Rabounski and Larissa Borissova with respect to their lifelong love of science and their immediate interest in the problem of liquid stars [408].

Dedication

This work is dedicated to those who, through their support, sacrifice, compassion, and understanding, permitted that my life be dedicated to science — my wife Patricia Anne* and our sons: Jacob,† Christophe,‡ and Luc.§

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*She insisted that this work be produced and that the proofs be gathered in one treatise.

†Jacob was the first to state that someday forty proofs would be published.

‡Chrisophe provided several of these lines of evidence in a paper we jointly authored based on the behavior of the solar winds and the structure of the Sun [48]. At the time, I had failed to recognize that these constituted additional proofs for condensed matter.

§Ever creative, Luc generated many of the figures in my relavent papers and has been a careful and just critic of both style and scientific presentation.

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