On the Presence of a Distinct Solar Surface: A Reply to Hervé Faye

Pierre-Marie Robitaille

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

In this exposition, the existence of the solar surface will be briefly explored. Within the context of modern solar theory, the Sun cannot have a distinct surface. Gases are incapable of supporting such structures. The loss of a defined solar surface occurred in 1865 and can be directly attributed to Hervé Faye (Faye H. Sur la constitution physique du soleil. *Les Mondes*, 1865, v.7, 293–306). Modern theory has echoed Faye affirming the absence of this vital structural element. Conversely, experimental evidence firmly supports that the Sun does indeed possess a surface. For nearly 150 years, astronomy has chosen to disregard direct observational evidence in favor of theoretical models.

Herbert Spencer was the first to advance that the body of the Sun was gaseous [1], but he believed, much like Gustav Kirchhoff [2], that the photosphere was liquid [3, 4]. For his part, Father Angelo Secchi [5, 6] promoted the idea that the Sun was a gaseous body with solid or liquid particulate matter floating within its photosphere. Soon after Father Secchi's second Italian paper [6] was translated into French by l'Abbé François Moigno, Harvé Faye made claims of independent and simultaneous discovery [3, 7, 8].

Harvé Faye almost immediately published his own work in *Les Mondes* [9]. In this communication, he deprived the Sun of its distinct surface. He based the loss of a solar surface on the gaseous nature of the interior and the associated convection currents. The salient sections of Faye's classic 1865 article stated: "*So then the exterior surface of the Sun, which from far appears so perfectly spherical, is no longer a layered surface in the mathematical sense of the word. The surfaces, rigorously made up of layers, correspond to a state of equilibrium that does not exist in the Sun, since the ascending and descending currents reign there perpetually from the interior to the superficial area; but since these currents only act in the vertical direction, the equilibrium is also not troubled in that sense, that is to say, perpendicularly to the leveled layers that would form if the currents came to cease. If, therefore, the mass was not animated by a movement of rotation, (for now we will make of it an abstraction), there would not be at its heart any lateral movement, no transfer of matter in the perpendicular direction of the rays. The exterior surface of the photosphere being the limit that will attain the ascending currents which carry the phenomenon of incandescence in the superior layers, a very-admissible symmetry suffices in a globe where the most complete homogeneity must have freely established itself, to give to this limit surface the shape of a sphere, but a sphere that is incredibly uneven*" [9].

In the same article, Hervé Faye emphasized that the photospheric surface was illusionary: "*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*" [9]. Though astronomy has denied the existence of a distinct solar surface as a question of utmost complexity involving opacity arguments [10], the conjecture was actually proposed by Faye in 1865 within a framework of questionable value [9]. Hervé Faye's contributions to solar theory have been extensively addressed [3] and many, like his famous *Les Mondes* communication [9], were not supported by mathematics. Early solar theory rested on vague hypotheses.

It was only much later that Faye's ideas would gain the support of mathematical formulation. In 1891, August Schmidt of Stuttgart wrote a small pamphlet which solidified Faye's conjectures [11]. Within two years, Schmidt received the support of Knoft and, in 1895, Wilczynski published a detailed summary of their ideas in the *Astrophysical Journal* [11]. The illusionary nature of the solar surface was finally supported by mathematics. James Keeler was the first to voice an objection to Schmidt's theory, responding immediately to Wilczynski's article [12]: "*But however difficult it may be for present theories to account for the tenuity of the solar atmosphere immediately above the photosphere, and however readily the same fact may be accounted for by the theory of Schmidt, it is certain that the observer who has studied the structure of the Sun's surface, and particularly the aspect of the spots and other markings as they approach the limb, must feel convinced that these forms actually occur at practically the same level, that is, that the photosphere is an actual and not an optical surface. Hence it is, no doubt, that the theory is apt to be more favorably regarded by mathematicians than by observers*" [12]. Twenty years after Schmidt proposed his ideas, they had still not gained the support of observational astronomers such as Charles Abbot, the director of the Smithsonian Observatory: "*Schmidt's views have obtained considerable acceptance, but not from observers of solar phenomena*" [13, p. 232].

In 1896, Edwin B. Frost [14] discussed Wilson's theory [15] in which sunspots represented depressions on the solar photosphere [3]. He maintained that the theory was not yet well established and required further investigation. Nonetheless, the highlight of his paper would be a comment relative to the existence of a true solar surface. Frost's work [14] formed an appropriate reminder that the presence of the solar surface had been long denied by those who, by advocating gaseous solar models, must reject solar structure as mere illusion: "*In speaking of levels we must proceed from some accepted plane of reference; and the most natural plane, or surface of reference, would be the solar photosphere. Here we are abruptly confronted by the theory of Schmidt, elaborated in a convenient form by Knoft, according to which the photosphere is merely an optical illusion, produced by circular refraction in the Sun itself, supposed to be a globe of glowing gas without a condensed stratum. Prominences, faculae, spots, and granulation are explained as effects of anomalous refractions due to local changes of density somewhere in the gas ball. This theory, worked out as it is by careful mathematical reasoning, deserves and has received respectful consideration. Nevertheless, in view of the physical improbability of Schmidt's primary assumption that in its outer portions the gaseous mass maintains its state without condensation, the physicist will feel obliged to reject the theory, which also suffers from the fundamental defect of failing to account for the solar spectrum on the accepted principles of physics. Moreover, any one who has with some continuousness studied the phenomena of the solar surface must affirm that he has observed realities, not illusions. The perspective effects on prominences as they pass around the limb, the motion and permanence of the spots, the displacements of the spectral lines on the approaching and receding limbs, and in fact all the phenomena concerned with solar rotation, are distinctly contradictory to Schmidt's theory. In dismissing it from further consideration, however, we shall take with us the important inference that refraction within and on the Sun itself may modify in some considerable degree the phenomena we observed*" [14].

Though Faye and Schmidt denied the presence of a distinct surface on the Sun, it was clear that observational astronomers were not all in agreement. The point was also made in 1913 by Edward Walter Maunder, the great solar physicist: "*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. They seem incompatible with the apparent structure of the photosphere, which is everywhere made up of a complicated mottling: minute grains somewhat resembling those of rice in shape, of intense brightness, and irregularly scattered. This mottling is sometimes coarsely, sometimes finely textured; in some regions it is sharp and well defined, in others misty or blurred, and in both cases they are often arranged in large elaborate patterns, the figures of the pattern sometimes extending for a hundred thousand miles or more in any direction. The rice like grains or granules of which these figures are built up, and the darker pores between them, are, on the other hand, comparatively small, and do not, on the average, exceed two to four hundred miles in diameter*" [16, p. 28].

That same year, Alfred Fowler [17] the British spectroscopist who trained as Lockyer's assistant, commented on problems in astronomy [18]. Fowler served as the first secretary of the International Astronomical Union [17]. Fowler's writings reflected that the ideas of Hervé Faye [9] and August Schmidt [11] continued to impact astronomy beyond 1913 [3, 4], even though observational astronomers were not convinced: "*The apparently definite bounding-surface of the Sun which is ordinarily revealed to the naked eye, or seen in the telescope, has such an appearance of reality that its existence has been taken for granted in most of the attempts which have been made to interpret solar phenomena… Thus the photosphere is usually regarded as a stratum of cirrus or cumulus clouds, consisting of small solid or liquid particles, radiating light and heat in virtue of their state of incandescence… An effort to escape from this difficulty was made in the view suggested by Johnstone Stoney, and vigorously advocated by Sir Robert Ball, that the photospheric particles consist of highly refractory substances carbon and silicon (with a preference for carbon), both of which are known to exist on the Sun...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*" [18]. It was well known that Johnstone Stoney [19] advocated that the solar photosphere contained carbon particles [4].

Even in the 21st century, astronomy has maintained that the Sun's surface is an illusion. For instance, in 2003, the National Solar Observatory claimed that "*The density decreases with distance from the surface until light at last can travel freely and thus gives the illusion of a 'visible surface'*" [20].

Nonetheless, spectacular images of the solar surface have been acquired in recent years, all of which manifest phenomenal structural elements on or near the solar surface. High resolution images acquired by the Swedish Solar Telescope [20–23] reveal a solar surface in three dimensions filled with structural elements. Figure 1 displays an image which is publicly available for reproduction obtained by the Swedish So-

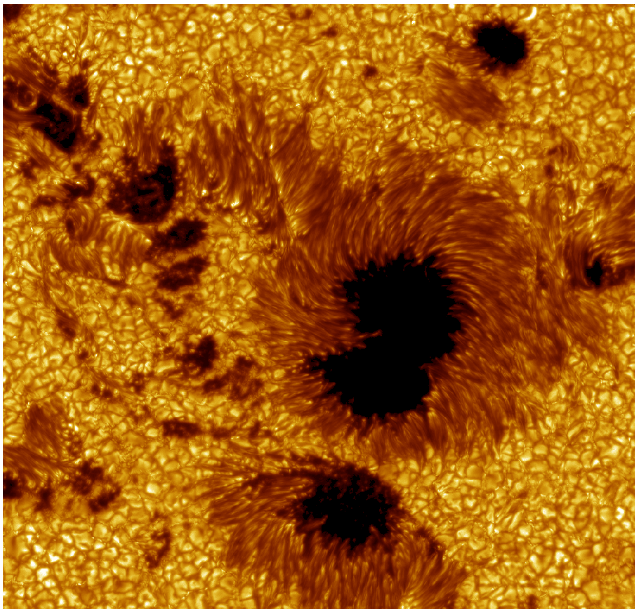

Fig. 1: Part of a sunspot group near the disk center acquired with the Swedish 1-m Solar Telescope by Göran B. Scharmer, Boris V. Gudiksen, Dan Kiselman, Mats G. Löfdahl, and Luc H. M. Rouppe van der Voort [21]. The image has been described as follows by the Institute for Solar Research of the Royal 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*" http://www.solarphysics.kva.se

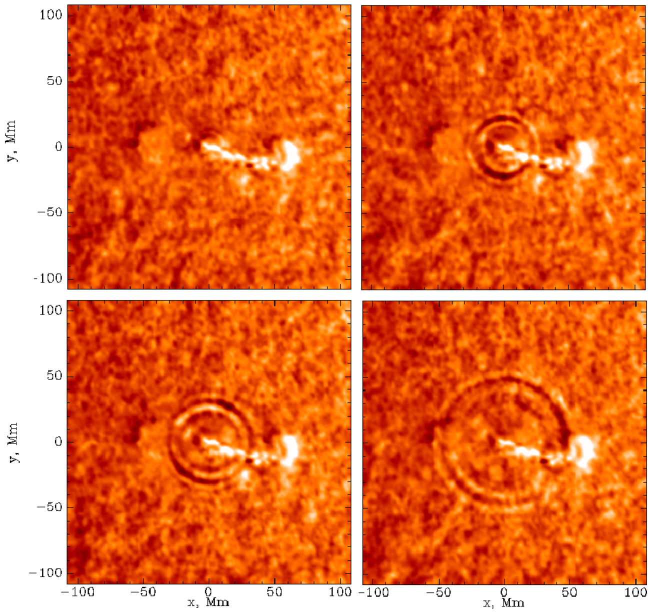

Fig. 2: Doppler image of a solar flare and the associated disturbance on the solar surface acquired by the NASA/ESA SOHO satellite. Such data was described as "*resembling ripples from a pebble, thrown into a pond*" [25]. Courtesy of SOHO/[Michelson Doppler Imager] consortium. SOHO is a project of international cooperation between ESA and NASA.

lar Telescope of the Royal Swedish Academy of Science. The author has previously commented on these results: "*The solar surface has recently been imaged in high resolution using the Swedish Solar Telescope [24, 25]. These images reveal a clear solar surface in 3D with valleys, canyons, and walls. Relative to these findings, the authors insist that a true surface is not being seen. Such statements are prompted by belief in the gaseous models of the Sun. The gaseous models cannot provide an adequate means for generating a real surface. Solar opacity arguments are advanced to caution the reader against interpretation that a real surface is being imaged. Nonetheless, a real surface is required by the liquid model. It appears that a real surface is being seen. Only our theoretical arguments seem to support our disbelief that a surface is present*" [24]. References [24] and [25] in the quotation referred to [21, 22] in the current work. A study of Lites et al. [23] illustrates how these authors hesitated to regard the solar surface as real, precisely because they considered that the Sun was gaseous in nature: "*However, since the angular resolution of the SST* [Swedish Solar Telescope] *is comparable to the optical scale of the photosphere (about one scale height), we may no longer regard the photospheric surface as a discontinuity; optical depth effects must be considered*" [23]. Though the authors reported three-dimensional structure, they added quotation marks around the word "surface" precisely because a gaseous Sun cannot support such a feature. They referred to the "optical depth unit surface", a concept inherently tied to gaseous models of the Sun. At the same time, the authors displayed a qualified desire for condensed matter: "*This gives the (perhaps false) visual impression of a solid surface of granules that protrude up a considerable distance from the surface, and that a raised structure is "illuminated" by a light source in the vicinity of the observer*" [23].

Beyond the evidence provided by the Swedish Solar Telescope and countless other observations, there was clear Doppler confirmation that the photosphere of the Sun was *behaving* as a distinct surface [25, 26]. In 1998, Kosovichev and Zharkova published their *Nature* paper *X-ray flare sparks quake inside the Sun* [25]. Doppler imaging revealed transverse waves on the surface of the Sun, as reproduced in Figure 2: "*We have also detected flare ripples, circular wave packets propagating from the flare and resembling ripples from a pebble, thrown into a pond*" [25]. In these images, the "optical illusion" *was now acting as a real surface*. The ripples were clearly transverse in nature, a phenomenon difficult to explain using a gaseous solar model. Ripples on a pond are characteristic of the liquid or solid state.

Hervé Faye's contention that the Sun was devoid of a real surface has never been supported by observational evidence; the solar surface has long ago been established. Though theory may hypothesize a gaseous Sun, it must nevertheless support observational findings. Perhaps, now that a reasonable alternative to a gaseous Sun has be formulated [27], astrophysics will discard the idea that the solar surface is an illusion, embrace the liquid nature of the Sun, and move to better comprehend this physical reality.

Acknowledgement

The Swedish 1-m Solar Telescope 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.

Dedication

This work is dedicated to my eldest son, Jacob.

Submitted on June 9, 2011 / Accepted on June 13, 2011
First published online on June 24, 2011

References

1. Unsigned (Spencer H.) Recent astronomy, and the nebular hypothesis. *Westminster Review*, 1858, v.70, 185–225.
2. Kirchhoff G. The physical constitution of the Sun. In: *Researches on the Solar Spectrum and the Spectra of the Chemical Elements*. Translated by H. E. Roscoe, Macmillan and Co., Cambridge, 1862, 23–31.
3. Robitaille P.M. A thermodynamic history of the solar constitution — I: The journey to a gaseous Sun. *Progr. Phys.*, 2011, v.3, 3–25 — a paper published in this Special Issue.
4. Robitaille P.M. A thermodynamic history of the solar constitution — II: The theory of a gaseous Sun and Jeans' failed liquid alternative. *Progr. Phys.*, 2011, v.3, 41–59 — a paper published in this Special Issue.
5. Secchi A. Sulla Teoria Delle Macchie Solari: Proposta dal sig. Kirchoff. *Bullettino Meteorologico dell' Osservatorio del Collegio Romano*, 31 January 1864, v.3(4), 1–4 (translated into English by Eileen Reeves and Mary Posani: On the theory of sunspots proposed by Signor Kirchoff, *Progr. Phys.*, 2011, v.3, 26–29 — a paper published in this Special Issue).
6. Secchi A. Sulla Struttura della Fotosfera Solare. *Bullettino Meteorologico dell' Osservatorio del Collegio Romano*, 30 November 1864, v.3(11), 1–3. (translated into French by François Moigno: Sur la structure de la photosphère du soleil. *Les Mondes*, 22 December 1864, v.6, 703–707; translated into English by Mary Posani and Eileen Reeves: On the structure of the photosphere of the sun, *Progr. Phys.*, 2011, v.3, 30–32 — a paper published in this Special Issue).
7. Faye H.A.E.A. Sur la constitution physique du Soleil — première partie. *Comptes Rendus*, 1865, v.60, 89–96.
8. Faye H.A.E.A. Sur la constitution physique du Soleil – deuxième partie. *Comptes Rendus*, 1865, v.60, 138–150.
9. Faye H. Sur la constitution physique du Soleil. *Les Mondes*, 1865, v.7, 293–306 (translated into English by Patrice Robitaille: On the physical constitution of the Sun — Part I. *Progr. Phys.*, 2011, v.3, 35–40 — a paper published in this Special Issue).
10. Robitaille P.M. Solar opacity: The Achilles heel of the gaseous Sun. *Progr. Phys.*, 2011, v.3 — a paper published in this Special Issue.
11. Wilczynski E.J. Schmidt's theory of the Sun. *Astrophys. J.*, 1895, v.1, 112–126.
12. Keeler J.E. Schmidt's theory of the Sun. *Astrophys. J.*, 1895, v.1, 178–179.
13. Abbot C.G. The Sun. D. Appleton and Company. New York, 1911.
14. Frost E.B. On the level of sun-spots. *Astrophys. J.*, 1896, v.4, 196–204.
15. Wilson A. Observations on the solar spots. *Phil. Trans. Roy. Soc.*, 1774, v.64, 1–30.
16. Maunder E.W. Are the planets inhabited? Harper & Brothers, London, 1913.
17. Unsigned. Obituary Notices: Fellows: Fowler, Alfred. *Mon. Not. Roy. Astron. Soc.*, v.101, 132-134.
18. Fowler A. Some problems in astronomy IV. Solar and stellar photospheres. *The Observatory*, 1913, v.36, 182–185.
19. Stoney G.J. On the physical constitution of the sun and stars. *Proc. Roy. Soc. London*, 1867, v.16, 25–34.
20. National Solar Observatory. Advanced Technology Solar Telescope — ATST. http://atst.nso.edu/files/press/ATST_book.pdf (accessed online on June 7, 2011).
21. Scharmer G. B., Gudiksen B.V., Kiselman D., Löfdahl M.G., Rouppe van der Voort L.H.M. Dark cores in sunspot penumbral filaments. *Nature*, 2002, v.420, 151–153.
22. MacRobert A. Solar faculae stand exposed. *Sky and Telescope*, 2003, v.106(4), 26.
23. Lites B.W., Scharmer G.B, Berger T.E., and Title A.M. Three-dimensional structure of the active region photosphere as revealed by high angular resolution. *Solar Physics*, 2004, v.221, 65–84.
24. Robitaille P.M. The solar photosphere: Evidence for condensed matter. *Progr. Phys.*, 2006, v.2, 17–21.
25. Kosovichev A. G., Zharkova V.V. X-ray flare sparks quake inside the Sun. *Nature*, 1998, v.393, 317–318.
26. Fleck B., Brekke P., Haugan S., Duarte L. S., Domingo V., Gurman J.B., Poland A.I. Four years of SOHO discoveries — some highlighs. *ESA Bulletin*, 2000, v.102, 68–86.
27. Robitaille P.M. Liquid metallic hydrogen: A building block for the liquid Sun. *Progr. Phys.*, 2011, v.3, 60–74 — a paper published in this Special Issue.