On the Structure of the Solar Photosphere

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Mary Posani (Department of French and Italian, The Ohio State University, Columbus, Ohio, 43221) and Eileen Reeves (Department of Comparative Literature, Princeton University, Princeton, New Jersey, 08544) provide a translation of Father Pietro Angelo Secchi's classic work "*Sulla Struttura della Fotosfera Solare*" as it appeared in *Bullettino Meteorologico dell' Osservatorio del Collegio Romano*, 30 November 1864, v.3(11), 1–3. Secchi's paper was immediately translated into French by l'Abbé François Moigno appearing on December 22nd, 1864 (*Sur la structure de la photosphère du soleil. Les Mondes*, 1864, v.6, 703–707). Moigno's translation prompted significant interest in the nature of the Sun throughout Europe, with rapid claims of simultaneous discovery by Harvé Faye (Faye H. *Sur la constitution physique du soleil — premiere parti*. Les Mondes, v.7, 293–306) and others. In this article, Secchi reiterated that the photosphere was composed of solid corpuscles floating on the transparent atmosphere of the Sun. Secchi concluded that the body of the Sun was gaseous based on his visualization of solar granules or "*willow leaves*" described by Nasmyth (Nasmyth J. *On the Structure of the Luminous Envelope of the Sun — In a letter to Joseph Sidebotham*. *Memoirs of the Literary and Philosophical Society of Manchester*, 1862, 3rd Series, v.I, 407–411). Secchi also referred to Magnus' work on solid particles in the gaseous flame (Magnus G. *Notiz über die Beschaffenheit der Sonne. Poggendorff's Annalen der Physik und Chemie*, 1864, v.121, 510–512; also in French *Notice sur la constitution du soleil*. *Archives des science physique et naturelles (Genève)*, 1864, v.20, 171–175). The works by Sechhi, Nasmyth, Magnus, and Faye would dominate astrophysical thought for the next 50 years.

In the first number of the *Bulletin* of this year we mentioned in passing the discovery by Signor Nashmyth concerning the structure on the sun which he named *willow leaves*, and which was subsequently confirmed by other astronomers, who found it preferable to call them *grains of rice*, because of the greater irregularity in the forms of the oval parts that they observed.

We said then that we did not yet have the means to examine this structure, because we lacked an ocular which would enable us to examine the solar image without a black lens, or darkener, and with a full aperture of the objective lens, an apparently essential condition for the accurate observation of these details. Recently, however, having received such an ocular through the kindness of Warren de la Rue, we made, as soon as the atmospheric circumstances permitted it, a series of observations, which we now report, reserving for another occasion a more extensive exposition.

The eyepiece of which we speak was formed with a plate of dark red glass inclined at 45° that reflects a small portion of the luminous rays, while it transmits a large portion of the others, and especially those of caloric value; the axis of the eyepiece by consequence remains at a right angle with the axis of the telescope. In the more northern climates, and especially in England, one can with this simple means of weakening of the rays look at the sun without danger to one's eyesight; but for us it is impossible, and we must add a slight darkener. The method of observing the reflection was proposed also by Signor Porro and P. Cavalleri: they had used, instead, two glasses under the angle of polarization, where, because the reflecting planes, were at right angles, the light becomes tolerable to the eye without any other adjustment, and remains white.

With one or the other method, one can visualize the sun much better than with colored glasses; the light remains white, and thus we can distinguish many details that were lost in the older method. However the polarizing system, introducing a double reflection, requires a great perfection in the optical reflectors, and thus, it is difficult to apply it to large instruments, in which the reflective surfaces should be rather broad. Instead of the reflective colored glass, one can substitute a prism by reflecting rays on the hypotenuse externally (and not by total reflection). However one cannot use a simple strip with parallel faces, because the second surface would give an image that could disturb that of the first.

Applying therefore this new eyepiece to Merz's great refractor, maintaining an aperture of its nine inches, we could immediately recognize a structure that truly differed greatly from what is commonly observed. The bottom of the solar disc appeared to be formed of a fine black mesh whose links were very thin and full of bright points. It was not so much the shape of the grid that surprised us — for we had seen it also at other times with older methods — as its blackness, which was truly extraordinary. It was such that we suspected some illusion, but in concentrating on certain darker points and finding them of unchanging and precise forms, we no longer remained in doubt about the reality of the aspect. Of this grid-like structure we can give an approximate idea in saying that the sun looked like a ordinary piece of rough paper seen through a strong microscope; on this paper the prominences are numerous and irregular, and where the light falls rather obliquely, the bottom of the grooves are almost black compared to the more elevated parts, which appear extremely white.

The grid-like solar structure seemed to us to offer nothing regular in those parts of the disc that are continuous, and thus the term *granular* appears very appropriate. Nevertheless, in the vicinity of the sunspots, that of *willow leaf* remains justified, because we actually see a multitude of small strips which terminate in rounded tips, and which encircles the edge of the penumbra and of the nucleus, resembling so many elongated leaves arranged all around. The granular structure is more visible near the spots, but it is not recognizable in the *faculae*; these present themselves like luminous clusters without distinguishable separation, emitting continual light without the interruption of dots or of that black mesh.

In the end, we have found the granular structure more notable and easy to distinguish in the middle of the disc than near the limb, and in the zones near the sun's equator, more than in the polar zones. The first [of these features] is without doubt an effect of the sun's refraction: in fact, the transparent atmosphere which encircles the sun must, because of its thickness and greater agitation, produce a greater confusion near the limb. We seemed to have recognized a trace of the effect of the refraction of this atmosphere in some of the systematic irregularities of the place of the spots near the edges, found by Signor Carrington in his admirable recent publication about sunspots. The polar regions, as is known, have a lower temperature and less agitation, and the spots do not appear there. This grid suggests that the spots are but an exaggeration of the minute holes which riddle the solar surface.

These are, in summary, the observations, which certainly raise a great number of questions. First of all, are these new findings? We believe that, in the end, these are the same granulations that have long since been pointed out by observers, under the name of "lucules" and "pores", and that with the new method they can better be distinguished. Because, since we can in this manner utilize a large aperture, the phenomenon of dilatation of luminous points or circles of diffraction that the objective lens forms are considerably diminished, and, as a consequence, we can better recognize the details, because each luminous center remains completely separated.

In the second place the rounded tips which surround the nuclei and the penumbrae are not new — at least not us — but rather are those that we have always indicated as evidence of the luminous currents that run to fill the emptiness of the spots. They are those types of currents that accumulate around the *nucleus*, and render the light appearing there greater in intensity than in the remoter regions of the penumbrae, just as the spokes of a wheel are more crowded together near the axle than towards the circumference. However, we must not omit the fact that with this means of observation, the appearance of a continuous current seems in many cases rather interrupted, and takes on instead the aspect of a multitude of torn fragments, or as Dawes says, of truncated straws that run towards the nucleus. But in any case, the more we study with attention these phenomena, the more it is *unacceptable* to us the idea that the spots are clouds. We do not hesitate to say there is still much that is mysterious in this structure, but certainly it has nothing to do with clouds, unless we wanted to say that the clouds are rather what form the luminous element, and that this incandescent material rushes in *cumulus* and in *cirrus* in the void of the spots, as we see sometimes in our atmosphere the *cumulus* and the *cirrus* run and fill in voids [in the sky].

Indeed this appearance suggests to us what is perhaps a bold hypothesis. As in our atmosphere, when it is cooled to a certain point, there exists a fine substance capable of transforming itself in fine powder and of forming clouds in suspension, (water transforming into so-called "vesicular" vapor or into small solid icicles), so in the enflamed solar atmosphere there might be an abundance of matter capable of being transformed to a similar state at the highest temperatures. These corpuscles, in immense supply, would form an almost continuous layer of real clouds, suspended in the transparent atmosphere which envelopes the sun, and being comparable to solid bodies suspended in a gas, they might have a greater radiant force of calorific and luminous rays than the gas in which they are suspended. We may thus explain why the spots (that are places where these clouds are torn) show *less* light and less heat, even if the temperature is the *same*. The excellent results obtained by Magnus, who has proved that a solid immersed in an incandescent gas becomes *more radiant* in heat and light than the same gas, seem to lend support to this hypothesis, which reconciles the rest of the known solar phenomena.

In the third place, one will ask oneself if such appearances are constant. It seems that we should say yes, since it has been discussed for two years, but to observe them takes no small practice and good instruments. Ours was extremely well made, with a red lens from England, but it showed little resistance to our [Italian] sun, and exploded into many pieces. Now we have substituted a prism, but it emits too much reflected light, and its surface is perhaps not perfectly polished. Nonetheless, we continue to see with clarity a grid and the other phenomena mentioned above. But the principal obstacle is the agitation of the air, which by mixing all these small shapes, makes a general confusion and flattens everything, for which reason they are only seen intermittently on those days that are anything short of perfectly calm. However, by moving the telescope slowly we can see the granulations much more easily than when we hold it fixed, and once they are recognized, it is easy to follow them and to study their forms.

May these indications suffice for now; the numerous other questions raised by this new method of observation and by this structure will be resolved with time. For now it is certain that this mode of observation can be said to have truly been a new conquest of practical astronomy.

Acknowledgement

Chris Corbally and Sabino Maffeo of the Society of Jesus and the Vatican Observatory are recognized for their assistance in providing Professor Robitaille with copies of Father Secchi's original papers as they appeared in the *Bulletino Meteorologico dell'Osservatorio del Collegio Romano*.

Submitted on April 28, 2011 / Accepted on April 28, 2011
First published in online on May 07, 2011