

ART. XLV.—*On the Janssen Solar Photograph and Optical Studies*; by S. P. LANGLEY.

MR. JANSSEN, in papers lately presented to the French Institute* has given an account of recent results in solar-photography, obtained by him at the observatory of Meudon, and from the comments of Messrs. Huggins, Lockyer, De la Rue and other competent judges, it has been understood that remarkable advances have been made over any before produced. A copy has been published in the *Annuaire du Bureau des Longitudes*, but details cannot well be studied from such a print, on paper, and details are here all-important. As the writer has received, through the courtesy of M. Janssen, a fine positive on glass; the only one he knows of, as having yet reached this country, and as it not only bears important testimony to facts which have rested hitherto in part on statements in previous numbers of this Journal, but is in every way so remarkable as to constitute an important step in the history of solar physics, an account will be given of it here.

The means used by M. Janssen for producing the photograph are understood to be a telescope of about five or six inches aperture, and twelve feet focal length, embodying the improvements introduced by Mr. Rutherford, and others of M. Janssen's own, the most important change being a shortening the time of exposure to $\frac{1}{3000}$ of a second, and at the same time an enlargement of the image. This involves a modification of the time of development, etc., and has evidently cost study and labor, the arduousness of which may be inferred from the perfection of the result.

As the photograph can only be made generally intelligible by some sort of illustration, the reader is referred to two papers in this Journal, the first in the number for February, 1874, where an article on the minute structure of the photosphere is illustrated by an Albertype plate, the second in March, 1875, accompanied by a steel engraving. The reader must also be detained briefly over a question of nomenclature which possibly has caused a misapprehension on Mr. Janssen's part, for the first paper undertook among other things, to specifically show that the elements of the photosphere were *not* "willow-leaf" or "rice-grain" like forms as had been commonly supposed. The term "rice-grain," it was carefully explained, was incorrect, and as an illustration imperfect. The name "rice-grain," for want of a generally accepted word, was used in the article, but under protest; especially as I had myself resolved these into minuter components, and carefully drawn specific instances

* *Comptes Rendus*, Oct. 29th and Dec. 31st, 1877.

of the foliate form and subdivision, specially calling attention to them in the plate, where they are found in two squares surrounded by a heavy outline. It is necessary to insist on the fact that purely optical methods had informed us of the nature of the constituents of the surface with a minuteness which photography has not even now attained. It was also stated in the first of these articles that the estimated mean distances between the centers of these composite objects ranged from $2''\cdot57$ to $1''\cdot42$ according to the degree of disintegration introduced by magnifying power, and the very important conclusion was reached that the light of the sun comes to us chiefly from an extremely small part of its surface—an indefinitely small part, but which is at any rate *less than one-fifth* of the whole. M. Janssen's impression that the true form and relative area of these has first been shown by the photograph is a misapprehension, though arising most naturally in part from the vicious nomenclature of the subject.

Until lately, photography has been useful, chiefly in fixing the positions and sizes of spots on the sun, rather than in studies of detail, which have hitherto been carried on with success only by the eye. The remarkable photograph before us begins a new order of things, for, though as we have said it does not reach absolutely all that the eye has yet caught, yet only those who have watched the sun with powerful instruments for years, can have enjoyed (and that rarely) the opportunity of seeing more than is here fixed for leisure study. It need hardly be said how immense is the gain of this opportunity for all to examine and verify deliberately; and it should be stated further that the photograph not only confirms previous results which have rested on the testimony of one or two individuals, but adds at least one important one of its own.

The plate before us is, as has been said, a positive, the solar image being 303^{mm} , or nearly twelve inches in diameter. The image viewed at a distance, shows the usual darkening toward the edge, though not quite uniformly all round, a circumstance probably not in the present case significant of any solar irregularity. Upon a closer view we see the coarse vague maculations or marblings* (formed as it seems to me by waves in the solar atmosphere, causing regions of greater thickness and consequently greater absorption by the heaping of the "rice grains"† and in some degree by their unequal distribution).

On a close approach we see the granular structure of the photosphere as it has never before been rendered in photography.

To give an idea of the precision of the photograph without the plate is hardly possible, but as the individual "grains"

* This is seen in the Albortype on removing it five or six yards from the eye where details are lost. The vagueness of the aggregations is in the original (i. e. in the sun itself.)

† Indicated all over the Albortype plates, and shown in specific details in the two designated squares.

may be here counted, I have placed on the positive a Rogers' reticule, consisting of very small squares, engine-divided on glass, which had been actually used on the sun for a similar purpose; and with its aid counted the "grains" in different parts of the plate not far from the center of the image, and taking the average I find a mean of about 5200 "grains" to the square inch, whence it appears, that at this rate, the plate actually exhibits within its circumference over half a million of these objects. From this measurement and the solar angular semi-diameter, it also appears that their mean distance in centers is $2''.2$ which is in close agreement with optical determinations made with corresponding powers. As these objects are rather complex than simple, I venture the opinion that should M. Janssen succeed in future in enlarging his photograph while retaining his present wonderful definition, that their mean distance will tend to appear still less.

We are now brought to what is perhaps the most remarkable feature of the plate, for a continued examination shows what undoubtedly has not been established by optical studies, that there are extensive regions where the "grains" are distinctly seen, and others adjacent where they are confused and blurred as if by bad definition. There are numerous alternations of these areas of disturbance; which are themselves of varying sizes; perhaps it would be more correct to say that the general surface presents this blurry character, with small regions where the definition is as sharp and clear as we have described it. Now,—a question evidently to be asked,—is this bad definition something in the solar atmosphere or our own? Does it mean a tremendous disturbance over hundreds of millions of square leagues, or a quivering of the air a few yards from the camera?

First we may ask, how far has there been any anticipation of such local disturbance on the sun, away from the spots and away from the faculæ as seen on the edge? I believe there has been, from telescopic study, a somewhat uncertain recognition that the photospheric structure differed at different times, but nothing like the variations shown here was anticipated. Doubtless these alternations of structure in adjacent regions, if once recognized, would be visible to the telescope, if sought, and it has, in fact, often been asserted that the aspect of the granulations varied at different times from solar causes; but with the telescope we lack the facility for deliberate comparison of one part of the disc with another, we obtain here, since owing to the undulations which we do know without doubt, are in our own atmosphere, our best vision is but momentary, and before we can turn from one part of the sun to compare it with another the opportunity is gone. The photograph, obtained as it is, in less than a thousandth of a second, may be taken many times in succession, and reproduce more or less indefinite images, yet

the thousandth exposure may fall in the brief instant of definition the observer patiently watches for, and then the results of this rare moment are made permanent by the camera.

Curiously enough, these disturbances of the solar atmosphere have been more distinctly *felt* by the thermopile, perhaps, than seen by the telescope. In 1874, after summing the results of thermal measurements, carried on at Allegheny to determine the heat of different parts of the surface, and after eliminating the effects of increasing absorption toward the limb, of spots, etc., there remained irregularities of a small order which showed either a hitherto unrecognized solar phenomenon, or (what might conceivably be the case) some undetected causes of minute instrumental error. The difficulty of determining which was great, for it was a characteristic of these minute fluctuations, that they were neither both fixed in position or magnitude, but incessantly, changed place and degree. Only after a year's further study, I felt confident that I had so far eliminated the smaller instrumental errors, that I was in presence of residual phenomena, which, however minute, were real; and which corresponded to continual fluctuations in the depth of the solar atmosphere all over the surface, in the nature of local disturbances caused by its currents, and I felt justified in announcing the existence of these—which I had never seen—in positive terms.*

Nothing could be more unexpected than the confirmation of these statements which the photograph offers, but it would be most unjust to M. Janssen's eminently original and valuable work, not to state that such anticipations, however positive, are obscure compared with the light thrown on this part of the subject by his methods. We say this, under the reserves already hinted, as to the difficulty of distinguishing by a single plate, the exact limits between the effects of solar and telluric disturbance; but so much at least appears to be solar, that we have here something very like evidence of great waves, in the solar atmosphere, obscuring the photospheric structure, and not only obscuring but changing it; for the currents appear to have altered the shapes of the grains, and their disposition. M. Janssen seems to consider the ultimate form of these grains as literal spheres, but it appears to me that his own admirable photograph bears other evidence. The components of these "grains" when undisturbed do indeed tend to dome-like forms, but these have always appeared to me to be but the extremities of filaments; extremities which aggregated, cause the "grains," and which lifted higher than their fellows cause the faculæ; the filaments themselves, being seen a little, here and there on the surface where bent over, and seen at all their length in the spots. In other words, we may compare the pho-

* *Comptes Rendus*, Sept. 6, 1875, p. 438.

tosphere to a field of grain in which from a bird's-eye view, we see, in a calm, only the rounded summits of the wheat. Let a wind blow fitfully over the surface, bending the crests here and there and showing more of the form of the straws. This is, it seems to me, the suggested explanation of the elongated form of the "grains" shown in such an interesting manner in M. Janssen's photograph where the action of solar currents is indicated and accompanied with partial obscuration. Let a whirlwind beat down the grain, showing the stalks lying every way exposed throughout their length—these are the filaments in a spot.

Of course the simile is imperfect and is not to be carried further. I can only venture conjecture as to what these "grains" really are, but I have always believed and still believe that they are not mere globular or bubble-like forms, but are associated with something beneath the surface most probably connected with ascending and descending gaseous currents, which in some way bring to that surface the heat from the interior, and carry back to it the gases which have been cooled by radiation, perhaps even to the point where precipitation occurs.

As to the question of the real solar origin of certain of the less definite forms on the plate we may say then, that it is known that certain peculiarities in our own atmosphere tend to impress themselves on the photographic plate, along with the solar phenomena, and it would be doubtless desirable, if possible, that two such photographs as we have here should be taken at intervals of five or ten minutes apart to eliminate this. It has been frequently asked why this is not done. But those who ask such a question are not familiar with the rarity of the instants in which *such* photographs can be taken. Two indeed can be taken at any interval, but those like the one before us, demand not only the finest mechanical and chemical methods and still more the highest skill, but atmospheric conditions so brief as to rarely or never last during even the short time mentioned.

Finally, then, though without two photographs of equal excellence taken within a few minutes of each other, it is perhaps impracticable to say *exactly* how much of the inequality of the plate is solar, it seems possible to state from the intrinsic evidence of the plate itself, that on the main features of its most interesting evidence as to the action of solar storms we may rely, and in this statement the writer, distrustful of his own knowledge of photographic processes, has sought the opinion of the most competent judge in these matters before expressing his own.

Our conclusion is, that M. Janssen has accomplished a remarkable, indeed, a wonderful, advance in solar photography, and that his success is not only a brilliant, but a useful one, for which he should have the thanks of every student of solar physics.

Allegheny, Penn., March 14, 1878.