XXX.—*On the Red Prominences seen during Total Eclipses of the Sun.*

Part II. By WILLIAM SWAN, F.R.S.E.

(Read April 19, 1852.)

In the first part of this paper, I have endeavoured to prove, that the red prominences seen during total solar eclipses, exist in the sun; and I now propose to state some views which have occurred to me as to the nature of those remarkable objects, and their possible connexion with other solar phenomena. It is not, however, without great misgivings that I venture on this subject; for we know so little of the sun, that any hypothesis regarding the constitution of his atmosphere, can amount only to a conjecture, possessing more or less probability according to the variety of the appearances it serves to explain, and the exactness with which theory and observation correspond in each case: and I am well aware that views which may seem probable to myself may not appear equally so to others, whose greater experience in observing the sun constitutes them better judges of such questions.

1. *On the Nature of the Red Prominences, and their Mode of Distribution in the Solar Atmosphere.*

For the reasons stated in the first part of this paper, I shall assume that the red prominences exist in the sun's atmosphere. They must, then, to use the words of Sir JOHN HERSCHEL, be "*cloudy masses, of the most excessive tenuity*;"* for being placed so near the sun, if their density approached that of the rarest terrestrial clouds, they could not fail to reflect an intensely brilliant light. Now this is far from being the case; for although they are by no means faint objects, neither are they very bright ones.

Another circumstance, which proves that the red prominences are gaseous and not solid bodies, is the overhanging form sometimes assumed by them, which, in the case of solid bodies, would result in the impending portions breaking off, and falling under the action of the sun's gravitation; and the same conclusion follows inevitably from the appearance, at the late eclipse, of a red mass completely detached from the moon's limb, and therefore evidently floating in the sun's atmosphere.†

The red prominences being thus obviously vaporous masses, I shall inquire, first, into the manner of their distribution in the solar atmosphere. Now the ob-

* HERSCHEL'S *Outlines of Astronomy*, par. 395.† M. ARAGO reasons in the same manner, in the *Annuaire* for 1852, p. 344.

servations of the late eclipse lead to the conclusion, that the cloudy matter composing them is diffused over the surface of the sun, to an extent much greater than probably has hitherto been suspected. This appears from the following facts :—

Mr HIND,* Mr DAWES,† and Mr GOOD,‡ who were situated near the southern edge of the moon's shadow, so as to witness a nearly tangential eclipse, saw a long range of red prominences extending, with *little interruption, over nearly a third part of the moon's limb*. Observers who were situated near the middle of the shadow failed to see the greater part of this long range or sierra, which, owing to the effects of parallax, was probably almost entirely hid from them by the moon; but they saw isolated prominences, which were distributed pretty uniformly all round the moon's circumference. A band of red light on the moon's limb, which preceded the reappearance of the sun, was likewise seen by Professor CHEVALLIER, Lieutenant PETTERSSON, Mr JACKSON, and Mr GRAY; and a similar fringe of red light was observed by HALLEY at the total solar eclipse of 1715.§ In describing this remarkable phenomenon, Lieutenant PETTERSSON relates, that “about 5^s before the reappearance” of the sun, he “saw along the edge of the moon, just where he expected the sun” to reappear, “a red fringe of rose colour,” on which the hook-shaped prominence, to which reference has so often been made already, “seemed to rest, and of which it seemed a part.”||

Obviously, the simplest view that can be taken of this phenomenon, is to regard the red fringe and the red prominences as of the same nature; and all the observations will then confirm the idea that the matter composing those objects *is distributed all round the sun*. It therefore seems probable, that when we are furnished with observations of a tangential phase of the eclipse from stations on the north side of the moon's shadow, it will be found that a sierra appeared towards the sun's north point, of which the detached prominences seen in that region, by observers situated near the middle of the moon's shadow, were only the highest peaks.

Now, in order to account for the phenomena exhibited by the spots on the sun, it has been supposed that they are portions of his comparatively dark body, seen

* Notice of R. Ast. Soc. for Jan. 1852, p. 67.

† *Ib.*, p. 69.

‡ Edinburgh New Philosophical Journal for Oct. 1851; or Astron. Nachrichten, No. 777.

§ Phil. Trans., vol. xxix.

|| Notice of R. Ast. Soc., p. 59.

A red fringe also appeared towards the beginning and end of the total phase at the eclipse of 1842. Thus M. SCHUMACHER, who witnessed the eclipse at Vienna, relates,—“Peu de temps avant la fin de l'éclipse totale, il s'éleva vers cette partie du disque lunaire d'où devait jaillir le première rayon de lumière, une étroite couche d'un rouge rosé qui s'étendait, peut-être, sur un espace de 70 à 80 degrés le long du bord de la lune, et qui disparut, ainsi que l'anneau lumineux et les montagnes rouges, aussitôt que le première rayon du soleil jaillit.”—*Annuaire* for 1846, p. 433.

M. STRUVE remarks.—“Je crois avoir vu, un instant avant la disparition du dernier rayon solaire, une couche rouge au bord de la lune, à 45 degrés environ du point où le soleil disparaissait.”—*Ibid*, p. 437.

through apertures, such as *i k* fig. 10, in a luminous envelope, *a b*, which surrounds him; and Sir WILLIAM HERSCHEL,* to explain the penumbra which generally encircles a solar spot, considers the luminous strata to be sustained far above the level of the sun's solid body, by a transparent elastic medium, carrying on its upper surface (or rather at some considerably lower level within its depth) a cloudy stratum *c d*, which being strongly illuminated from above, reflects a considerable portion of light to our eyes, and forms the penumbra, while the solid body shaded by the clouds reflects none. The temporary removal of both strata, but more of the upper than the lower, as represented in the figure, he supposes effected by powerful upward currents of the atmosphere, arising, perhaps, from spiracles in the body, or from local agitations.†

Since, then, it has been shewn to be highly probable that the matter composing the red prominences is distributed with little interruption all round the sun, we may conceive the luminous strata of the solar atmosphere to be surmounted by an *envelope (e f,) of clouds*, of which only the higher portions are visible beyond the moon's limb, at the central phase of a total eclipse; and which then constitute the red prominences. If it be thought that the hypothesis of two envelopes of cloud, one above and another below the luminous strata of the sun's atmosphere, introduces too great complication, we may avoid the objection, by supposing that the envelope which occasions the penumbræ around the spots penetrates the luminous stratum, and exists, although in greatly different degrees of density, both above and below it.

If, then, we conceive that a stratum of cloudy matter surrounds the sun, of which the red prominences are the higher portions, the serrated appearance of the long range of prominences, seen by Mr DAWES and Mr HIND, sufficiently indicates that its general surface is exceedingly uneven, presenting the appearance of being covered with numerous eminences or ridges. But these irregularities are small when compared with the large hook-shaped prominence, and its companion the detached cloud, which were seen by most of the observers of the eclipse. The altitude of the hook-shaped prominence has been variously estimated at from 1'·5 to 3'; and, by actual micrometrical measurement, it was found to be 1' 41"·5 just before the sun reappeared.‡ Adopting this measurement, its actual height must have exceeded 47,000 miles, or about six times the diameter of the earth. The existence of bodies of such magnitude indicates some immense local disturbance in the sun's atmosphere, but not greater than that indicated by the solar spots, some of which Sir JOHN HERSCHEL states to have been observed, "whose linear diameter has been upwards of 45,000 miles, and even, if some records are to be

* Philosophical Transactions, 1801.

† HERSCHEL's Outlines of Astronomy, par. 389.

‡ This is the mean of observations by Mr WILLIAMS and Mr STANNISTREET. Notice of R. Ast. Soc. for January 1852, pp. 54, 55.

trusted, of very much greater extent ;”* and yet spots of such immense magnitude seldom last much longer than six weeks, so that their edges must often approach at the rate of 1000 miles a-day.†

Now, as the spots have been supposed to arise from upward currents causing apertures in the sun’s luminous atmosphere, I conceive the higher red prominences, or those which remain visible at the middle of the total phase of a central eclipse, may in like manner be formed (as represented at *f* and *g*, fig. 10) by the same, or similar currents, in the sun’s atmosphere, breaking through the envelope of cloud that surrounds him, bending back the edges of the apertures they have formed, and sometimes carrying up detached masses of cloud, such as that which was seen at the late eclipse. We may, however, suppose the envelope of cloud to be sometimes simply raised (as at *h*), without being broken through ; and in that state it may form the conical prominences which were observed at the late eclipse.

Since the prominences reflect, they must also absorb light ;‡ and thus, the hypothesis which has been proposed regarding them, *assumes the presence of an envelope of cloud surrounding the sun’s luminous atmosphere, capable of absorbing part of his light, and subject to occasional interruptions of its continuity.*

If, then, such an envelope surrounds the sun, it will probably be connected with various solar phenomena. Let us now inquire whether any appearances presented by the sun afford additional evidence of its existence.

2. *On the Increased Brightness of the Corona in the neighbourhood of the Red Prominences.*

According to my observations of the late eclipse, the hook-shaped prominence was accompanied by increased brightness of the corona in its neighbourhood. (Plate XII.). Now this is a necessary consequence of the supposition, that the higher red prominences are the upturned edges of apertures in the envelope of cloud surrounding the sun ; for the absorbent medium having been removed in forming the apertures, the sun’s light ought to illuminate the corona more powerfully over an aperture than elsewhere. At the same time, it does not follow that all red prominences should be near bright portions of the corona ; for a prominence may be formed by the cloudy stratum being simply raised, without being perforated.

* Dr WILSON of Glasgow, who, by observing a large solar spot, was led to the discovery that it was an aperture in the sun’s luminous atmosphere, estimates the depth of its nucleus as “ not less than a semidiameter of the earth below the level of the sun’s spherical surface.” See his highly interesting paper, *Philosophical Transactions*, vol. lxiv., 1774.

† HERSCHEL’s *Outlines of Astronomy*, 1851, par. 386.

‡ In certain circumstances steam has a red colour. May not the rose colour of the prominences indicate a property of the vapour composing them analogous to that possessed by steam, or, if they consist of aqueous vapour, identical with it? Professor FORBES, to whom we are indebted for our knowledge of the red colour of steam, regards it as the principal or only cause of the rosy tint observed in clouds.—See his interesting paper, *Edinburgh Transactions*, vol. xiv., p. 371.

3. *On the Diminished Brightness of the Sun's Disc towards its Edges.*

That the sun is surrounded by some medium capable of absorbing his light, has been considered to be satisfactorily proved by the rapidly diminishing brightness of his disc towards the edges; which, Sir JOHN HERSCHEL remarks, "can only arise from the circumferential rays having undergone the absorptive action of a much greater thickness of some imperfectly transparent medium (due to greater obliquity of their passage through it) than the central rays."* He further states, that if the sun had not an atmosphere capable of reflecting light, the sky ought to appear completely dark at a total eclipse of the sun. The existence of the corona round the moon is therefore a proof, he adds, that the sun has an atmosphere capable of reflecting, and therefore of absorbing light.

Now, the absorbing medium indicated by the corona is evidently an extremely diffuse atmosphere, extending to a great distance from the sun's surface; for the breadth of the corona is certainly not less than the sun's radius. It can, however, be easily shewn, that the darkness of the sun's limb compared with his centre, if it arises from the absorption of light by the solar atmosphere, must be occasioned, almost exclusively, by the absorptive power of those portions of the atmosphere which are near the surface of the sun.

It will be sufficiently accurate, for this purpose, to assume that the sun is a sphere, of which A B, fig. 11, represents the surface, and $ab b' a'$ a stratum of the solar atmosphere, of so small thickness that its absorptive power may be regarded as uniform. As the whole absorption, in passing through such a thin stratum, will be very small, we may safely assume that the light, in traversing a certain thickness of the absorbent medium, will thereby acquire no additional facility for penetrating the remaining portions of it; equal aliquot parts of the incident light will therefore be absorbed in passing through successive equal thicknesses of the stratum.

Suppose all the sun's atmosphere excepting $ab b' a'$ to be removed.

Let 1 = the number of intromitted rays,

$\frac{1}{m}$ = the number of rays lost by absorption and dispersion when the light has traversed a unit of thickness,

$$M = 1 - \frac{1}{m},$$

t = the thickness aa' of the stratum;

Then the number of rays that escape absorption after passing to the eye in the direction aa' , perpendicularly through the stratum, will be

$$\left(1 - \frac{1}{m}\right)^t = M^t.$$

* Outlines of Astronomy, par. 395.

On the other hand, rays proceeding to the eye from the edge of the sun in the direction Bb , will pass obliquely through the stratum, which, from its small thickness, may be regarded as a lamina, bounded by parallel planes perpendicular to Bb . The thickness bb' of the medium traversed by the rays, will therefore be

$$t \sec BbC = t \operatorname{cosec} \alpha,$$

where α is the angle BbC ; and the number of rays that escape absorption will be

$$\left(1 - \frac{1}{m}\right)^{t \operatorname{cosec} \alpha} = M^{t \operatorname{cosec} \alpha}$$

Then, putting h_1, h_2 , for the apparent brightnesses of the sun's disc at A and B, as seen from the earth, the ratio of h_2 to h_1 will be that of the numbers of rays transmitted at the points $b'a'$; or,

$$\frac{h_2}{h_1} = \frac{M^{t \operatorname{cosec} \alpha}}{M^t} = M^{t(\operatorname{cosec} \alpha - 1)}$$

Now, the nearer ab is to the surface of the sun, the smaller is α , and for a small angle, $\operatorname{cosec} \alpha$ will be very large; hence, for a stratum near the surface, since M is less than unity, the ratio of h_1 to h_2 will be very great. On the other hand, as the distance of the stratum from the surface increases, $\operatorname{cosec} \alpha$ approaches to unity, and h_1 becomes nearly equal to h_2 .

It thus appears that the effect of the oblique transmission of the lateral rays through the sun's atmosphere in increasing the absorption of those rays, and hence diminishing the apparent brightness of the sun's limb, as compared with his centre, is very great in the case of those strata of the atmosphere which are near his surface; but that it rapidly diminishes, as the strata are more and more removed from the surface of the sun. Hence, even if we suppose the solar atmosphere equally dense and equally absorptive throughout its whole extent, the diminished brightness of the sun's limb contrasted with that of his centre, would be due chiefly to the action of those portions of the atmosphere which are near his surface. But, besides this, from the necessarily rapid diminution of their density, the absorptive action of the successive strata of the solar atmosphere on light must quickly diminish, as their height above the surface increases; and this will conspire, with the continually lessening obliquity with which the sun's lateral rays traverse the higher strata of his atmosphere, so as to render their action in causing the diminished brightness of the sun's limb probably insensible.

Since, then, the observed darkness of the sun's limb, is due chiefly to a comparatively thin layer of atmosphere near his surface, the very notable amount of that darkness renders it necessary for us to regard those portions of the atmosphere as very highly absorptive. The thin envelope of cloud which has been supposed to surround the sun, near his surface, is precisely such an agent as would produce the phenomenon now under consideration; and we may thus, perhaps, regard the diminished brightness of the sun's limb as a corroborative proof of the existence of such an envelope.

4. *On the Faculæ and Luculi seen on the Sun's Disc.*

The supposition that the sun is surrounded by an envelope of cloud, occasionally penetrated by apertures, may serve to explain the *faculæ* and *luculi* seen on the solar disc. These are portions of the sun's surface brighter than the rest; and they have been supposed to be ridges in his luminous atmosphere, indicating violent agitation in their neighbourhood.* May they not, however, be simply apertures in the envelope of cloud? If such apertures exist, the sun's surface seen through them will appear more luminous than elsewhere; for his light passing through the apertures will escape, more or less, the absorption suffered by the rays which traverse the envelope itself. This explanation of the *faculæ* is quite consistent with the well-known fact, that they are best seen when near the sun's edge. Thus, if the dotted line hi (fig. 11) represent the surface of the envelope, and ef $e'f'$ two apertures in it, seen from a distant point in the prolongation of CA ; the ray g will be contrasted with Ah , which has passed perpendicularly through the envelope, while the ray g' is contrasted with Bi , which has passed obliquely through the envelope, and therefore suffered more absorption than Aa . It is evident, then, that the nearer a facula approaches the sun's limb, the more strongly will it contrast with the brightness of the surface in its neighbourhood, and the more distinctly will it be seen.

If, however, the *faculæ* be regarded as ridges in the sun's luminous atmosphere, their brightness, compared with the rest of the sun's disc, and their increased distinctness when near his limb, may also be explained by supposing that a thin envelope of cloud surrounds the sun; for if $ABb'a'$ be the envelope, and Aa the height of a ridge, the point a will appear brighter than the rest of the surface, because its light has only traversed the thickness aa' of the absorbing medium, while that from the rest of the sun's surface has passed through the whole thickness AA' , and has consequently been more absorbed. Again, if a ridge has the position bd , so as to be seen projected on the sun's limb,—supposing all the atmosphere above ab removed,—we should have the light from a and b , which would not then suffer absorption, contrasted in the one case with light which had passed through the thickness Aa , and in the other through the greater thickness Bb of absorbent matter. The contrast at b would evidently then be greater than at a . If now the rays from Aa traverse together the remaining portions of the sun's atmosphere, they will be almost equally absorbed, and the relative brightness of the points aA will not be sensibly altered; the same will be true with regard to Bb . Hence the contrast of the brightness of the ridge, when compared with that of the sun's general surface, will still be greatest at the sun's limb.†

* SIR WILLIAM HERSCHEL. Philosophical Transactions, 1801.

† SIR WILLIAM HERSCHEL, who regards the *faculæ* as ridges, does not seem to hold that opinion very confidently. In his paper, already noticed, he only once states that they "have the appearance of elevations."—(Phil. Trans. 1801, p. 84.) Mr DAWES, however, has recently

It may be further observed, that if the red prominences are portions of the envelope of cloud, thrown upwards by currents in the sun's atmosphere, which tend to produce faculæ by ultimately rupturing the envelope, the prominences will have a physical connexion with the faculæ, but no *necessary* connexion with the solar spots.

It is well known, however, that conspicuous faculæ often occur in the neighbourhood of groups of spots; and the same upward currents in the sun's atmosphere, which are supposed to occasion the spots, by removing a portion of his luminous envelope, may also occasion the faculæ, by removing a portion of the superincumbent cloudy strata. The occurrence, immediately before an eclipse, of faculæ near the sun's limb, with or without accompanying spots, ought therefore to indicate a quarter where red prominences might be expected to appear; and at least one coincidence in the position of spots and red prominences was actually observed at the late eclipse. A group of spots was seen by me immediately before the eclipse, about $1'5$ from the sun's limb, and to the west of his vertex. The angle of position of this group, reduced to the sun's north point, was ascertained to be $288^{\circ} 47'$; and the conspicuous hook-shaped prominence, which appeared during the totality, was found to be situated at $282^{\circ} 8'$ from the sun's north point. The hook-shaped prominence may therefore have been connected with faculæ in the neighbourhood of the group of spots. The region where spots occur is limited to a zone, extending about 25° or 30° on either side of the sun's equator; and Mr LASSELL observes, that, as at the late eclipse "some prominences appeared on parts of the sun's limb not usually traversed by spots, the connexion between the two is not made out."* This remark, however, does not apply to the supposed occasional relation between the prominences and the faculæ; for although faculæ are seen most abundantly in the neighbourhood of spots, they also occur by themselves, and have been observed all over the sun's disc; so that the prominences which are supposed to be connected with them might appear at any point in the sun's limb.

5. *On the Irregular Illumination of the Corona seen during Total Eclipses of the Sun.*

Let us next inquire how the hypothesis of an envelope of cloud surrounding the sun's luminous atmosphere, consists with the phenomena of the corona.

There are remarkable appearances in the corona, which seem quite inexpli-

observed a facula projecting beyond the sun's limb (R. Ast. Soc. Notice for April 1852). With reference to that observation, it may be permitted to remark,—that considering the rapid degradation in brightness of the sun's disc towards the edges,—it is evident that the dark glasses used in observing the sun may, to some extent, diminish its apparent diameter, the light from the extreme edge of the disc being possibly too feeble to be seen through the glass. A portion of the sun's limb brighter than the rest would be less encroached on from this cause, and would thus appear to project beyond the general outline. Irradiation would also conspire to increase this effect. The action of the dark glasses, in diminishing the sun's apparent diameter, may also be one of the causes of the anomalous variations in observations of the sun's diameter.

* R. Ast. Soc. Notice, p. 53.

cable, on the mere hypothesis that the sun possesses an atmosphere capable of absorbing light uniformly, but which are perfectly consistent with the supposition that he is surrounded by a stratum of cloudy matter, strongly absorbing his light, but subject to frequent interruptions of continuity. These are, the distinctly radiated structure of the corona, and the appearance of bundles of rays, separated by comparatively dark intervals. The different observers of the late eclipse are not quite agreed as to the appearance of the corona; but, upon the whole, there is a strong preponderating testimony to the effect that its illumination was far from uniform. Thus Mr SNOW says,—The corona “appeared not to be uniformly disposed, but in irregularly radiating bundles or masses.”* M. LASSELL states, that the corona “was radiating, some of the rays appearing *longer* than the rest, but the irregularity was not great;”† and Mr WILLIAMS, that “it was divided by radial lines, and presented the appearance of luminous brushes shot out from behind the moon.”‡ Dr BOUSTED saw the corona “somewhat rugged, and more extended towards the left of its upper part.”§ In a drawing of the eclipse, communicated to me by Lieutenant PETERSSON, he represents the corona as consisting of detached brushes of light; and he particularly points out the occurrence of a dark interval, 100° to the east of the sun’s vertex. Mr ADIE saw “brighter coruscations shooting through it all round, extending beyond the general light of the corona, and having a kind of flickering appearance;”|| and, according to Mr HIND, rays of light extended through and beyond the corona.¶ Mr AIRY represents the corona as consisting of bundles of rays, very strongly marked; and he describes its structure as radiated, and as terminating, though very indefinitely, in a manner resembling the ornament round a mariner’s compass.** To me the corona seemed strongly radiated (see Plate XII.), the bright rays being separated by intervals of comparative darkness; and there were brilliant beams of light at particular points, brighter than the rest of the corona, and visible beyond its general outline. The largest and brightest of those beams or masses of light was situated $61^{\circ} 8'$ to the east of the sun’s north point. Its form was conoidal, having its base towards the sun. The other beams were in the form of extremely acute cones, with their vertices towards the sun, and their sides apparently converging towards his centre.

It appears from these observations that there is something existing at the surface of the sun capable of intercepting his light unequally, and of causing a want of regularity in the illumination of the corona. For if we suppose the light to be transmitted uniformly by the sun’s atmosphere, it would follow that rays proceeding from different points of his surface would cross each other’s paths, and blend their effects; so that however irregular the luminosity of the surface, the illumination of the corona, at a little distance, would approach to uniformity. Its

* R. Ast. Soc. Notice, p. 47. † Ibid., p. 52. ‡ Ibid., p. 54. § Ibid., p. 57.

|| Edinburgh New Philosophical Journal for October, p. 375. ¶ R. Ast. Soc. Notice, p. 67.

** Ibid., p. 60.

radiated structure seems therefore to indicate the existence of something tending to limit the transmission of the rays to directions normal to the sun's surface, and capable of absorbing them more powerfully at certain points than at others. The bright beams of light in the corona strongly resembled sunbeams shining through narrow apertures in clouds; and it was indeed that resemblance which first led me to entertain the idea that an envelope of cloudy matter surrounds the sun. Immediately after witnessing the late eclipse, when I reflected on the striking want of continuity I had observed in the illumination of the corona, I was strongly impressed with the conviction that something existed near the surface of the sun which intercepted his light more at certain points than at others. It then occurred to me, that as the red prominences, from their power of reflecting light, must also absorb it, the medium which absorbed the sun's light irregularly, and caused the unequal illumination of the corona, might be no other than the matter composing the red prominences; that matter being supposed to constitute an envelope surrounding the sun, of which the red prominences are only the higher, and probably the rarer portions.

If the faculæ are apertures in the envelope of cloud, as has been supposed, it will follow that faculæ near the sun's limb may be connected with the bright beams in the corona. If, then, a considerable portion of the sun's surface near his limb were intersected by numerous branching faculæ, with openings gradually increasing in width towards the centre of the group, we should probably have a mass of light in the corona like that represented in Plate XII., which was seen at the late eclipse about 30° to the east of the sun's vertex. On the other hand, light proceeding from a single long facula in the sun's limb, presented to the eye endwise, might occasion the appearance of the narrow bright beams which were seen in the corona; and a considerable variety of effects might be produced by faculæ whose positions were differently inclined to the visual direction.

The following queries embody the hypothesis which I have now ventured to propose regarding the red prominences, and the other solar phenomena which I have supposed to be connected with them:—

1. May not the sun's luminous atmosphere be surrounded by an *envelope of cloud* capable of absorbing part of his light, and having the property of appearing red when seen by reflected light?

2. As the spots on the sun have been supposed to be formed by upward currents in his atmosphere, may not the same, or similar currents, force up portions of the envelope of cloud, and sometimes actually rupture it?

3. May not the higher portions of the envelope of cloud be seen projecting beyond the moon's limb during the total phase of a solar eclipse, and thus constitute the *red prominences*?

4. May not this envelope be the chief agent in causing the diminished brightness of the sun's disc towards his edges, owing to the greater thickness of the

envelope, traversed obliquely by the rays, which reach the eye from points near his limb?

5. May not the *faculae* and *luculi*, or bright portions of the sun's disc, be *apertures* in the *envelope*, through which his light passes with less absorption than at other places?

6. Will not the supposed connexion of the higher red prominences with the *faculae*,—or apertures in the absorbent envelope,—explain the observed increase in the brightness of the corona in the neighbourhood of such prominences?

7. Will not the supposition, that an envelope of cloud surrounds the sun, capable of absorbing his light, but penetrated with apertures, so as to allow more light to escape at certain points than at others, explain the want of uniformity in the brightness of the corona, and the brilliant beams of light which occur in it?

When the preceding paper was read, I had not, as has already been noticed, seen M. ARAGO'S Memoirs in the *Annales* for 1846 and 1852; nor had I seen the fourth volume of HUMBOLDT'S *Cosmos*, recently published, which contains an exposition of M. ARAGO'S views regarding the red prominences. In these circumstances, it may be proper to insert here some passages from those works, which, if I had obtained access to them at an earlier period, I should have embodied in the preceding pages.

“Après avoir constaté que le soleil se compose d'un corps obscur central, d'une atmosphère nuageuse réfléchissante et d'une photosphère, nous devons naturellement nous demander s'il n'y a rien au delà, si la photosphère finit brusquement et sans être entourée d'une atmosphère gazeuse peu lumineuse par elle-même, ou faiblement réfléchissante. Cette troisième atmosphère disparaîtrait ordinairement dans l'océan de lumière dont le soleil paraît toujours entouré.”*

“Il faut admettre une enveloppe extérieure qui diminue (étient) moins la lumière qui vient du centre, que les rayons qui viennent sur le long trajet du bord à l'œil. Cette enveloppe extérieure forme la couronne blanchâtre dans l'éclipses totales du soleil.”†

“L'éclipse de 1842 nous a mis sur la trace d'une troisième enveloppe située au-dessus de la photosphère, et formée nuages obscurs, ou faiblement lumineux.”‡

“Jetons un coup d'œil rapide sur une quatrième hypothèse, celle suivant laquelle les protubérances seraient assimilées à des nuages solaires nageant dans une atmosphère gazeuse. Nous ne trouverions aucun principe de physique qui put nous empêcher d'admettre l'existence de masses nuageuses de 25,000 à 30,000 lieues de long, à contours arrêtés et affectant des formes les plus tourmentées.”§

“Dans la nombreuse catégorie des taches du soleil, quelle est la place qu'

* *Annuaire* for 1852, p. 342.

† ARAGO, quoted by HUMBOLDT, *Cosmos*, MURRAY'S Edit., vol. iv., Notes, p. ciii.

‡ *Annuaire*, for 1846, p. 464.

§ *Annuaire* for 1852, p. 345.

occuperaient les nuages de la troisième enveloppe ? *Peut-être* ces nuages produisent-ils les pénombres isolées, les pénombres sans noyau. Les taches de ce genre ne sont pas très-communes ; jamais leur étendue totale n'est une partie aliquote considérable de la surface solaire."*

From these passages, it appears that in M. ARAGO's opinion, the sun, besides being surrounded by a stratum of dark clouds, and a *photosphere*, has, beyond them, and enveloping them, a third atmosphere, in which are floating clouds, which, when seen during a total eclipse, form the red prominences.

This is the same view as that stated at the beginning of my paper, on the authority of Sir JOHN HERSCHEL, and to which I have ventured to add the hypothesis that the clouds causing the prominences form of themselves a nearly continuous envelope, floating in the third atmosphere, and above the photosphere. If, then, a formal enumeration of the sun's envelopes were made, according to *my view* there would be *four*. 1st, The dark clouds below the photosphere. 2d, The photosphere itself. 3d, The envelope of cloud so often referred to ; and, 4th, The sun's atmosphere surrounding all, and in which the other three solar envelopes may be supposed to float.

That M. ARAGO does not regard the clouds which occasion the red prominences as forming a continuous envelope, appears evident from several considerations. In enumerating the envelopes surrounding the sun, he never mentions more than *three*,—viz., the cloudy envelope below the photosphere, the photosphere itself, and a third atmosphere surrounding it. This third atmosphere is also spoken of as a third envelope, and as an exterior envelope ; but these different expressions are evidently employed to denote, as one envelope, the sun's exterior *atmosphere, along with the clouds floating in it* ; for if the atmosphere and the clouds were reckoned *separately*, there would be *four* envelopes and not *three*. The passage where the third envelope is said to be formed of clouds (*formée de nuages*) would, indeed, if read by itself, seem to convey the idea of an envelope, composed of clouds exclusively ; but other passages sufficiently prove that this is not M. ARAGO's view. Thus the expression, " the clouds *of* the third envelope " indicates the idea that those clouds are not themselves the envelope, but detached masses floating in it. Moreover, since the terms, third envelope, third atmosphere, and exterior envelope, are obviously all used in the same sense,—the exterior envelope or third envelope cannot consist alone of a continuous stratum of clouds forming the *red* prominences ; for it is elsewhere described as causing the *white* corona (*couronne blanchâtre*), which, in the case supposed, would be *red*, and not *white*.

It seems also highly probable, that if M. ARAGO had supposed that the clouds forming the red prominences also constitute a continuous stratum surrounding the sun, the phenomenon of a band of red light seen at the end of the total phase of solar eclipses,—which he believes† is caused by the presence of red promi-

* Annuaire for 1846, p. 465.

† Ibid. for 1842, p. 440, *et seq.*

nences,—would have been adduced in proof of the existence of such a stratum ; but no such inference is drawn from that phenomenon.

Besides this, M. ARAGO supposes that the clouds forming the red prominences probably occasion the isolated spots which have no central nucleus (*penombres isolées, penombres sans noyau*) ; but, as he immediately adds, that those spots are by no means common, and when they occur, occupy but an inconsiderable part of the sun's disc, it is evident that he must conceive the clouds which form them to be isolated, and widely scattered,—an idea quite inconsistent with the supposition, that they form a continuous envelope surrounding the sun.

From these considerations, it appears evident that M. ARAGO's hypothesis regarding the red prominences, involves simply the idea that those objects are clouds floating in the sun's atmosphere ; and therefore, that his opinion is the same as Sir JOHN HERSCHEL's, whose views, stated at p. 461, form the groundwork of the hypothesis I have now proposed. In addition to the idea that the red prominences are clouds,—which, according to HUMBOLDT, was first announced by M. ARAGO,—I have endeavoured to shew, that those clouds probably form a continuous envelope surrounding the sun ; and I have further supposed that this envelope is the chief agent in causing the diminished brightness of the sun's disc towards the edges,—that when apertures occur in the envelope, they possibly constitute the faculæ on the solar disc,—and that those apertures also occasion the bright rays in the corona seen during total eclipses of the sun.

Sun's Vertex

W. Swan, Del^t

Engraved by W. & A. K. Johnston, Edin^r

THE TOTAL ECLIPSE OF THE SUN.

JULY 28TH 1851.

As seen towards the end of the totality by M^r W. Swan at Göteborg
in Sweden, with a telescope magnifying 28 times.