Contributions to the atmospherology of the sun

Peters, Christian Heinrich Friedrich

[Erscheinungsort nicht ermittelbar], 1855

3

Professor R. Wolf, at Zürich
very respectfully
from
C. H. F. Peters

It is obvious that these proportional parts are equally useful in taking account of second differences whenever it is necessary.

After taking out the log. variations corresponding to the given longitude and latitude, it will only be necessary to multiply them by the excess of these data above their nearest argument values to find the corrections for the tabular A. R. and Decl.

The correction for change in the obliquity needs no further explanation.

---

4. Contributions to the Atmospherology of the Sun. By Dr. C. H. F. Peters, of Cambridge.

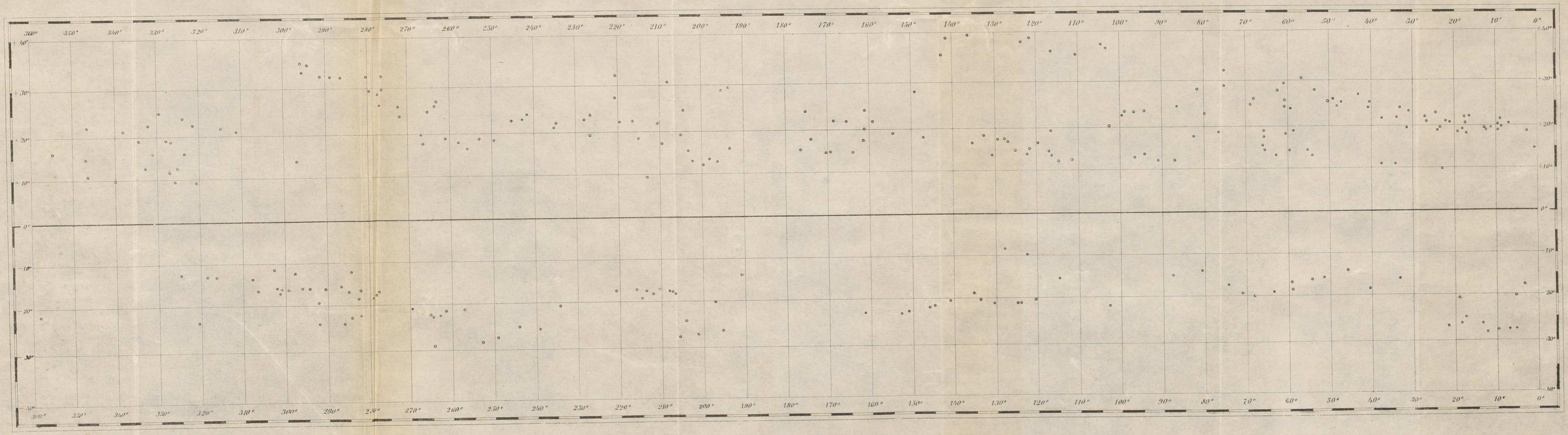
Our knowledge of the physical constitution of the surface of the sun has made very little or no progress since the time of the elder Herschel. This would prove, either that Herschel's observations are so complete that nothing more remains to be investigated, or that the *central* body of our system has been neglected, while nebulæ and double stars, moon and planets, have been the object of very elaborate researches. Each alternative seems to be the case. By employing similar means, and with the same method, that is to say by simple *contemplation*, it will scarcely be possible to discover anything not already reported by that eminent observer. Only a more favorable sky, as I shall show by example hereafter, may disclose some new and important phenomena. Unfortunately, all the more powerful telescopes are mounted in climates not well adapted for solar observations. But there remains another way of investigating the processes producing those singular changes in the sun's atmosphere, which exhibit themselves as spots, faculæ, and otherwise, a way which has been set aside too much in this subject; I mean by *numerical calculation.* Certainly it is not enough to tell the number of spots for every day, nor to determine occasionally from a larger one the elements of rotation; it seems necessary to follow the spots or faculæ in their relation to the sun's body and to each other, by computing their heliographic positions from exact measurements, made, if possible, from day to day. This way is, indeed, a little troublesome, but nevertheless promises very interesting results.

(From the Proceedings of the American Association, of 1855)

I have the honor to lay before the Association some conclusions drawn from a series of observations which I began at Naples in the year 1845, especially with the view to ascertain whether on the sun's surface certain fixed localities do exist, where the spots are originating.

I may state beforehand, that all the measurements are taken with the equatorial of the Observatory at Capodimonte, the telescope of which, of four feet focal length and three inches and a half aperture, is a most excellent one, from the hands of Reichenbach. For examining the physical phenomena the ten-foot Fraunhofer was recurred to, provided with a contrivance suggested by Melloni, cutting off the rays of heat, but not disturbing those of light. Of every spot presenting something definite, the difference from the sun's centre was determined in right ascension by repeated transits, and in declination by the three-foot circle, at intervals, when possible, of one or two days. Moreover, the principal systems of spots were sketched, a precaution necessary in order to avoid mistakes in identifying the spots observed on subsequent days. From the so determined differences in A. R. and Decl. the heliocentric situation relative to the sun's equator has been computed, by assuming for the beginning of the year 1846 the longitude of the equator's ascending node upon the ecliptic to be 75° 13′, its inclination 7° 9′, Mr. Laugier's values, which I have found pretty near the truth. Thus are obtained the heliographic latitude and an angle, which I shall call the *argument of latitude;* it is the longitude reckoned from that point of the equator which, at that moment, is in the ecliptic or in the node. But in comparing together different spots observed at different times, it is convenient to establish a first meridian, and (since there is no fixed point always visible upon the sun) I have considered that meridian as the first, which at the beginning of 1846 (Naples mean noon) passed through the ascending node. Then, in order to find the meridian actually passing, a knowledge of the daily motion, or of the time of rotation, is required. The value employed (14° 2′.04 for the daily motion, or $25^{d}.652$ for the time of rotation) has been deduced as a mean from the observations of all the spots. For the following investigation, the first three months have been excluded as being less accurately observed, and moreover disjoined by an interruption of several months. Likewise the observations following October, 1846, were too isolated to be made use of.

A HELIOGRAPHICAL MAP OF THE SOLAR SPOTS OBSERVED IN THE YEARS 1845-46.



Thus an uninterrupted series of thirteen months remained, from September, 1845, to October, 1846, subministering 813 places of 286 spots. These have been projected in the accompanying map, as far as their mean places.

The first fact, now, which offers itself, in comparing the heliographic places of one and the same spot for different days, is, that the spots are not invariably attached to the sun's surface, but have *proper motions.* Before stating this, due regard should be had to the probable errors that the determination of the compared places may be liable to. This probable error, in my observations, of a difference between a spot and the sun's centre, resulted to be in A. R. $3''$ in arc, in Decl. nearly $5''$, consequently in all $6''$. This would produce in the heliocentric place an error of 215 times $6''$ multiplied by the secant of the angle at the sun's centre between earth and spot, 215 being the ratio of the mean distance of the earth to the sun's semidiameter. Near the centre of the sun's disc, then, the probable error would be about $20'$; for the angle at the sun's centre equal to $45°$ it would be $30'$, and it would increase rapidly as the spot approaches the limb. I sought to avoid this increase by repeating the observations the more, the nearer the spot was to the limb. And therefore, on the whole, the probable (or more justly speaking the *mean*) error of the heliocentric place as arising from this source may be taken equal to $20'$. But a second source we find in the variability of the shape of the spot itself from one day to the other. There is a continual change going on in the spots ; less perhaps in the isolated ones, more in those which are in the neighborhood of others, and seem to form part of a system. However, those cases where the change of form was too manifest may be omitted ; and we may assume, then, on the average, that two places of a spot as determined on different days ought to agree within half a degree. But now we meet differences of several degrees. Does this not indicate clearly a movement of the spot, especially if, as often, in a *series* of determined places these differences appear to be affected with the same sign ?

Wherever in nature a motion is observed, inducement is given to research of laws and of forces causing it. Though, at the first glance, a decrease in latitude seemed predominant, still sometimes this appeared so mixed up with a movement in different sense, that it is only after having carefully examined and combined the circumstances under which every spot was situated, and after having paid special attention to the arising of the individual spots, that I dare to pronounce the two following theses: —

1. *All the spots have a tendency to move towards the equator.*

2. *Whenever a spot is breaking out in the neighborhood of another, the latter is removing itself towards the opposite side.*

The first or general kind of motion, concealed, if the interval of time

TABLE A.

Heliographic Latitudes of Spots which performed an entire Revolution.

(Mean of the determinations in each appearance.)

Spot. No.	No. of Obs.	Mean Epoch of Observation.	Heliographic Latitude.	Spot. No.	No. of Obs.	Mean Epoch of Observation.	Heliographic Latitude.
		d.	° ′			d.	° ′
6	5	—106.818	—27 21	80	2	+ 93.479	+31 46
286	4	83.568	25 54	81	6	118.718	28 31
				77	4	142.733	24 32
94	6	— 99.442	+19 54				
86	6	76.984	17 12	279	3	+111.394	+18 52
				272	5	136.972	18 37
180	3	— 65.313	—17 30				
177	2	41.566	17 9	244	3	+109.764	—24 6
				232	5	134.401	22 11
151	1	— 34.066	+14 30	210	3	159.661	21 41
147	5	14.780	14 24				
				261	3	+109.764	+21 12
15	7	— 24.777	+18 32	260	2	133.463	20 42
10	7	+ 2.423	18 29				
8	4	24.960	18 4	208	3	+134.649	+17 41
				202	3	159.661	17 42
35	5	+ 7.820	+21 48				
31	2	27.552	19 16	79	1	+176.028	—17 41
				53	5	198.841	16 4
26	3	+ 8.007	+18 0	48	4	224.531	14 27
19	4	27.742	17 38				
				226	5	+244.259	+28 34
229	6	+ 23.018	—18 11	212	1	266.024	26 44
228	2	50.071	17 35				
233	4	78.775	16 50	135	2	+211.034	—21 50
				118	5	233.428	21 7
22	5	+ 29.186	+21 11	120	3	256.356	21 7
18	4	57.725	21 8				
				102	4	+232.256	+36 36
137	3	+ 43.365	+17 39	110	2	255.052	35 25
129	2	67.540	15 56				
119	3	95.634	14 16	273	4	+248.560	+11 32
				264	2	274.921	9 3
249	2	+ 56.579	—15 40				
247	1	74.033	14 40	57	4	+255.288	+13 56
				41	1	278.957	10 27
61	1	+ 91.934	+24 32				
66	4	118.799	23 58	68	3	+254.062	+13 0
				43	1	278.957	10 35

is short, by the disturbed motion, becomes quite obvious in longer intervals, as, for example, in an entire revolution. The annexed Table A contains the latitudes of those spots which reappeared on the eastern limb of the sun's disc after they had disappeared on the western. All the spots, the identity of which could be made out, have been inserted; none excluded. The numbers (which are the means of the single determinations during one appearance, corresponding to the mean epochs) show without exception a decrease in latitude, the unique instance of the increase of one minute being entirely overthrown by the amount of the probable error.

A general proper motion of the spots towards the equator being recognized, the question is raised naturally: Have they any motion also in longitude? and in what sense? to the east or to the west? The solution of this question is intimately connected with the determination of the time of rotation. For it is clear, if all the spots had an *equal* proper motion in longitude, the time of the sun's rotation, since it is deduced from the spots, would be wrong. If the spots move by a certain amount to the west, the sun's rotation will be found too great exactly by that amount; if to the east, it will be too small. In other words, it is the time of rotation of the spots which results, and not that of the sun itself. By employing then the same value in the comparison of observations made at two different epochs, the spot will appear to have been at rest, while it really has changed its place. If the general motion in longitude differs as to its amount for several spots, then a time of rotation will be derived from them, which includes the *average* general motion. Thus the value $25^{d}.652$, which I have given before, and which is made use of for the longitudes in the map, is affected by the average general motion of all the spots observed more than once. By means of this average value of the time of rotation, now, the successive places leave differences so significant that there can be no doubt of a very considerable motion parallel to the equator. The displacements in longitude seem even far more considerable than those in latitude. The annexed Table B gives some examples. Whether there be a common motion, and in what sense, cannot be decided in the present state of our knowledge of the sun's rotation. According to the mode in which this latter is established, the sum of the positive differences always will equal the sum of the negative, whatever be the amount of motion in common, as the

TABLE B.

Table exhibiting the proper Motion of some Spots in Heliographic Longitude.

Epoch.	Longitude.
No. 6 (−27°).	
d.	° ′
−110.042	6 50
109.043	6 12
108.073	5 56
103.987	6 57
102.944	8 8
No. 9 (+21°).	
+55.023	7 58
58.134	8 57
60.018	9 5
62.966	9 28
No. 17 (−26°).	
−110.042	11 9
109.043	12 55
108.073	12 49
103.987	14 29
102.944	15 9
No. 32 (+19°).	
+58.134	25 27
60.018	24 9
62.966	22 45
No. 44 (+24°).	
+167.023	38 2
170.028	39 44
172.019	41 17
174.031	42 52
No. 53 (−16°).	
+194.152	55 5
196.956	52 25
199.028	50 9
201.043	50 42
203.023	49 56
No. 67 (+29°).	
+6.983	58 41
8.015	60 8
9.022	61 13
9.989	62 7
11.013	63 25

Epoch.	Longitude.
No. 72 (+14°).	
d.	° ′
+113.027	68 21
115.033	66 2
118.201	64 48
119.938	64 57
122.025	64 54
No. 81 (+29°).	
+113.027	73 28
115.033	73 27
118.201	75 10
119.938	75 53
122.025	76 27
124.081	77 56
No. 90 (+11°).	
−24.100	91 21
22.044	92 10
20.996	92 47
19.991	89 43
17.990	88 4
No. 105 (+12°).	
−77.037	116 28
74.940	114 48
73.861	113 19
No. 113 (+38°).	
+226.148	115 58
228.036	117 58
231.032	120 46
233.916	122 26
236.041	125 19
238.113	127 22
No. 124 (+17°).	
+91.934	130 39
95.025	129 57
99.942	127 18
No. 130 (−19°).	
+119.938	136 39
122.025	135 45
124.081	135 9
126.087	134 24

Epoch.	Longitude.
No. 144 (+20°).	
d.	° ′
−99.828	163 42
98.963	163 52
97.842	162 11
96.103	160 28
93.169	160 31
91.120	159 32
No. 158 (+28°).	
+258.965	194 27
263.014	195 10
266.024	195 25
270.885	196 13
No. 204 (−28°).	
−38.075	251 44
35.113	251 42
34.066	252 52
32.884	252 53
31.090	253 35
29.086	254 58
No. 219 (+19°).	
+238.113	269 54
241.026	266 14
244.411	264 29
No. 242 (−16°).	
+101.021	292 59
103.026	291 34
106.124	291 10
110.142	289 11
113.027	289 39
No. 275 (+25°).	
+24.960	328 26
27.020	329 9
28.084	329 29
30.902	330 43
No. 286 (−22°).	
−86.029	360 16
84.081	358 30
83.074	357 39
81.089	357 16

greater movements will show an excess, the slower ones a defect, according to phoronomical principles. Nevertheless, there are some reasons which make me incline to the opinion, that the general direction of the movement is towards the *west*. Farther on, I shall return to this question; but in this place, the following observation may be made, namely, that a new spot bursts out almost always to the *east* of an older one, very seldom to the west. Since it is of some interest, the linear velocity has been computed for some of the spots which seemed imbued with a somewhat considerable motion (as on the annexed Table C). Here are velocities up to between 300 and 400 miles the hour, which is not so extraordinary, considering that the sun's diameter is 112 times that of the earth, and that the strongest hurricanes on the earth are supposed to possess a velocity of 120 miles an hour. For the sake of comparison, it may be mentioned that the velocity of rotation of a point at the sun's equator is between four and five times as great as of a point at the earth's equator; or as the latter is nearly 900 miles, the former is about 4,000 miles, the hour.

TABLE C.

Some of the greater Absolute Velocities per hour of Solar Spots observed in Geographical Miles.

Spot.	Velocity.	Spot.	Velocity.
No. 12	20	No. 273	109
232	29	144	129
215	43	230	129
202	57	17	132
22	62	82	153
118	63	286	168
132	73	95	169
53	75	113	207
242	84	35	222
19	92	88	238
204	98	90	261
81	102	67	277
66	106	219	366

The second fact which I wish to draw attention to, results by combining together the heliographic positions of different spots, and may be pronounced, for the present, in the following thesis: —

In certain localities of the solar surface, the spots arise more frequently than in others.

A glance upon the map shows immediately that the spots are arranged in two girdles or belts, one to each side of the equator.

This observation is not entirely new. Already Galileo had stated, that all the spots are found within an equatorial zone, the limits of which he fixed at 29°. The Jesuit Scheiner extended these limits to 30° ; Messier, to 31° ; Lalande, Delambre, and Méchain, to 40° ; Laugier, to 41°, north and south. The remark, that the neighborhood of the equator itself is barren of spots, is of a more recent date. I see that Sir John Herschel, in his " Cape Observations," has come to a similar conclusion. Still, this region, too, is not entirely destitute of the capability of producing spots. In March, 1845, I saw some so near to the equator as 3°. But these are rather rare. In regard to the outer limits of the zone, perhaps the same may be said. By Lahire, a spot is related in 70° latitude. I observed one during several days in 50° 24′, and a remarkable facula as high up as 67°. Of the northern spots, inserted in the map, the greatest number is near to the parallel of 21° ; of the southern, the greatest number is near to 17°. Here it is proper to make a distinction between *individual* spots, and *systems* or groups of spots. The spots forming a system show clearly an identical perturbation generating them in the same moment. The relative frequency in different parallels of latitude of the individual spots, as well as of the systems of spots, is represented by the curves in the annexed drawing. (Plate I.)

The establishing of *both* the co-ordinates of some fixed points as particularly productive of spots, is certainly of the greatest importance. The observations of thirteen months have shown themselves insufficient to be decisive as to the positions in longitude, though they give some intimations. The great obstacle is the uncertainty about the time of rotation, as including the proper motion in longitude. Observations continued during four or five years, and duly computed, probably would carry us a considerable step farther in this research, and consequently nearer to the true philosophy of the sun's nature. At all events, it is reasonable to suppose that the proper motion is only small in proportion to the rotary motion, so that the latter may be assumed to be right at least *approximately*. With this assumption, my computations give several instances of spots breaking out at *nearly* the same place after intervals of two and three hundred days, whilst in the intermediate time that place was plain and smooth like the rest of the sun's surface, not indicating any sign of disturbance. Avoiding, for obvious reasons, those parallels where the appearances are more condensed, I wish to point out as examples :

280° long. and +30° lat.
200° " " +12° "
115° " " +35° "
15° " " —28° "

In order to justify the assumption, that our knowledge of the time of rotation cannot be very much out of the way, and that, of course, the proper motion of the spots can be but a small fraction of the rotary motion, I may mention the results obtained by two modern philosophers, who attempted to derive the time of the sun's rotation from observations of terrestrial temperatures. The value deduced from the long series of Innsbruck and Paris temperatures by Professor Nervander, of Helsingfors, is 27.26 days for the synodical, or 25.367 for the tropical revolution. Mr. Buys-Ballot, in Utrecht, in the same manner making use of the Belgian and other thermometrical observations, gives 27.692 days for the synodical, which would be 25.742 for the sidereal revolution.* I made some trials, to arrive at a direct conclusion of the rotation by other ways, which, for a longer series of observations, will be found effective. One is based upon the similitude of certain figures of the spots when they are first outbursting. Among these figures is an elliptic arrangement not uncommon, and two pair of those observed by me may well be considered as arisen in the same locality. A second way would be precisely by the assumption of the identity of those places, which I indicated before. But their number is still too small, and the uncertainty deriving from the extent of those localities too great, for deriving from them any exact result.

After having exposed several facts, which result from the numerical investigation of measurements, I may now relate briefly some telescopic observations, one of which, favored by the beautiful sky of Naples, is worthy the particular attention of other observers. In order to make better understood this phenomenon, I ought to trace shortly the biography of spots, such as on the whole I have noted it in the suc-

* These two results differ to about the same amount as the determinations by means of spots. The mean value of Delambre's and Lalande's researches is 25.021 days; Laugier found from 29 spots 25.34 days, the particular spots varying from 24.28 to 26.23 days; Dr. Böhm formed equations of condition for 13 spots, which gave 25.821 with a probable error of only 0.024 days. The value which I have adopted as a preliminary one, from 286 spots, 25.652 days, is intermediate between all these different determinations.

cessive stages of their appearance. The spots arise from insensible points, so that the exact moment of their origin cannot be stated; but very rapidly they grow in the beginning, and almost always in less than a day they arrive at their maximum of size. Then they are stationary, I would say in the vigorous epoch of their life, with a well defined penumbra, of regular and rather simple shape. So they sustain themselves for ten, twenty, and some even for fifty days. Then the notches of the margin, which, seen with a high magnifying power, always appears somewhat serrate, grow deeper, to such a degree that the penumbra in some parts becomes interrupted by straight and narrow luminous tracts; — already the period of decadence is approaching. This begins with the following highly interesting phenomenon. Two of the notches from opposite sides step forward into the area, overroofing even a part of the nucleus; and suddenly from their prominent points flashes go out, meeting each other on their way, hanging together for a moment, then breaking off and receding to their points of starting. Soon this electric play begins anew, and continues for a few minutes, ending finally with the connection of the two notches, thus establishing a bridge, and dividing the spot in two parts. Only once I had the fortune to witness the occurrence between *three* advanced points. Here, from the point A a flash proceeded towards B, which sent forth a ray to meet the former, when this had arrived very near. Soon this seemed saturated, and was suddenly repelled; however, it did not retire, but bent with a rapid swing towards C; then again, in the same manner, as by repulsion and attraction, it returned to B, and after having oscillated thus for several times, A adhered at last permanently to B. The flashes proceeded with great speed, but not so that the eye might not follow them distinctly. By an estimation of time and the known dimension of space traversed, at least an *under* limit of the velocity may be found; thus I compute this velocity to be not less than two hundred millions of metres (or about one hundred thousand miles) in a second. The process described is accomplished in the higher photosphere, and seems not at all to affect the lower or dark atmosphere. With it a second, or rather third, period in the spot's life has begun, that of dissolution, which lasts sometimes for ten or twenty days; during which time the components are again subdivided, whilst the other parts of the luminous margin too are pressing, diminishing, and finally overcasting the whole, — thus ending the ephemeral existence of the spot. Rather a good chance is required for observing the remarkable phenomenon which introduces the covering process, since it is achieved in a few minutes, and it demands, moreover, a perfectly calm atmosphere, in order not to be confounded with a kind of scintillation, which is perceived very often in the spots, especially with fatigued eyes. The observer ought to watch for it, under otherwise favorable atmospherical circumstances, when a large and ten or twenty days' old spot begins to show strong indentations on its margin.

In the foregoing exposition I have avoided carefully all theoretical speculations and hypotheses. I have brought before you the facts simply as they resulted from observations combined by vigorous numerical computations. However insignificant these single results may appear, still they may lead to some important consequences relative to our knowledge of the nature of the sun. And as the method generally employed in natural philosophy consists in building upon a few facts a hypothesis as to the cause, which hypothesis then, by other facts, ought to be tried, and either rejected or confirmed, thus also to the astronomer it may be permitted, in an object which, until now, was rather more physical, than within the reach of quantitative determination.

At present there is no more any doubt about the view of Herschel (or rather Wilson) with regard to the constitution of the sun in general. Above the solid and opaque nucleus rises the atmosphere, of a nature perhaps similar to ours; this again is surrounded by a second atmosphere, luminous, and very thin. The spots are openings in both the atmospheres, leaving visible the dark solar body; the penumbra is the limb of the lower atmosphere. But now, with regard to the origin of the spots, Herschel seems to have inclined to an idea which is neither natural nor corresponding to the phenomena. According to him, the atmosphere is set in strong motion, by a cause, which he does not define nearer, is then thrown against high mountains, and thus the openings in the luminous matter are produced. This idea is indeed a little strange; and it seems to have been abandoned by modern philosophers, though without advancing any other theory in its place. All the facts of observation have impressed me strongly with the supposition, that on the surface of the solar body something exists similar to *volcanoes*, breaking out and emitting gaseous matter, in a manner similar to the terrestrial volcanoes. These gases pass easily and speedily through the lower or dark atmosphere, until they arrive at the photosphere. Of this we have nothing in the least degree analogous upon our planet; but it appeared to me, under all circumstances, to possess in a high degree the propriety of viscosity. This viscosity at first opposes the gases, and faculæ are formed. But the gases succeed in overcoming the coherency, breaking the photosphere from beneath, usually first in numerous small points, which very soon become larger, as in the mean time the gaseous matter had collected, now bursting out with greater elasticity. These gases really have been seen; they have been observed outside of the photosphere; they are identical with the *rosy light* in the total eclipses of the sun. Especially the eclipse of July, 1851, has left no doubt, as well about the cloudy nature of this light as about its connection with faculæ and spots. Are the purple-colored ridges, which sometimes have been seen on the dark ground of the spots, perhaps also nothing else than the gases elevated above the photosphere, illuminated, and seen by projection upon the dark nucleus? With a very clear sky, the bottom of the larger spots appears never black, but always brownish or purplish, the outlines of the ridges widened, less distinct, outwashed, and the ridges themselves resemble then stronger colored plots. The gaseous exhalations explain completely the appearances of the faculæ, inflated bubbles covered by the viscous luminous matter, always preceding the outbreak of a spot, surrounding it in its first stage, but then disappearing. When the gases are effecting their escape, the luminous matter is pressed aside; hence the removal of a neighboring spot, agreeably to observation. The very sudden increase after the first opening is made, the then following stationary size, the reopening of spots nearly closed by the covering process, are necessary consequences of the emanation of elastic matters. The gases start from the surface of the nucleus impressed with the velocity of rotation corresponding to that point; in ascending to higher regions, where the velocity of rotation is greater, they remain behind to the west; on reaching the photosphere, they are opposed by the viscous tenacity of the latter, by overpowering which they lose a part of their vertical velocity, and press towards the west, communicating this direction of motion to the luminous matter surrounding the spot, and of course to the spot itself. The observation I have before made, namely, that a new spot breaks forth in most cases on the *east* side of an older one, is now accounted for by a repeated eruption of the volcano, after it had been reposing for a short lapse of time, during which the older opening has advanced towards the west. The volcanoes are situated principally in two zones or belts, on both sides of the equator, to which phenomenon geologists will find an analogy in the greater mountain chains upon our globe ; hence the frequency of spots on certain parallels. If this theory of volcanic eruptions which I have dared to advance shall be confirmed, especially by the establishment of certain fixed eruptive points in longitude, then, with some confidence, we may compare the moon to a country of extinguished volcanoes, our planet to a volcano languishing in eruptions, and the sun to the seat of volcanoes in a prodigious state of activity.

---

5. Method of determining Longitudes by Occultations of the Pleiades. By Professor Benjamin Peirce, of Cambridge. (Communicated by Permission of Professor A. D. Bache, Superintendent of the Coast Survey.)

1. The determination of longitudes by occultations of the stars appears to be the most exact of all astronomical methods for such determinations, and deserves therefore a most careful examination, in order to ascertain the greatest degree of accuracy of which it is susceptible, and the surest method of securing such accuracy. The sources of error are partly those of observation, and partly those of theory. The errors arising from observation are of two classes ; first, there are those which are special to the observations of the occultations ; and, secondly, there are those which are general and inseparable from the theoretical defects.

2. The probable error of the direct observation of an occultation has been investigated by Commander C. H. Davis, from simultaneous observations made by different observers at the same place. From his researches, which were communicated to the Association at Washington, it appears that this probable error is about a fifth of a second of time, so that the ultimate probable error of the mean of this class

of observations cannot exceed a twentieth of a second of time. If, therefore, the theoretical defects can be eliminated by proper precautions and a sufficient accumulation of observations, longitudes may be obtained by this method, of which the probable error shall be decidedly inferior to a tenth of a second of time.

3. It is obvious that, with the present uncertainty of the lunar theory, isolated occultations cannot approach this degree of accuracy in the determination of longitudes. But well-determined groups of stars are essential to correct the lunar elements and rectify the places of the stars themselves. The present plan is to carry out the suggestions of Walker, in his report to the Superintendent published in 1851, by combining all the known observations of occultations of the Pleiades, and using them to correct the lunar semidiameter, the mutual positions and changes of position of the stars of this group, to test and correct the formulæ for lunar parallax, to determine the irregularities of the moon's limb, and, finally, to correct the longitudes of the places of observation.

4. Of the various forms of computation which might be adopted, I have selected that which is derived from the stereographic projection of the sphere, in which the star Alcyone *is the pole of projection.* The advantages of the stereographic projection consist in the circularity of the projections of all the spherical circles, so that the moon is represented by a circle on the plane of projection. The advantage of placing the pole of projection at the star Alcyone is, that the distances and relative positions of the projected places of the stars are only affected by the differences of their proper motions, and the small differential effects of aberration. There may be a doubt whether the somewhat greater simplicity of the formulæ, in the case in which the pole of projection coincides with that of the celestial equator, should not cause this form of projection to be preferred; and it may be advisable, in order to insure accuracy, to conduct the computations, independently, by each method.

5. As the basis of computation, the places of the stars have been taken from Bessel's investigations, which are contained in the first volume of his *Astronomische Untersuchungen*, in the article entitled *Beobachtungen Verschiedener Sterne der Plejaden.* The places of the moon are taken from the Nautical Almanac, or from the "Tables of the Moon," constructed for the American Ephemeris, and the