

X. *On a definite arrangement, and order of the appearance and progress, of the Aurora Borealis ; and on its height above the surface of the earth. In a letter to DAVIES GILBERT, Esq. M.P. President of the Royal Society. By the Rev. JAMES FARQUHARSON, Minister of the Parish of Alford, Aberdeenshire.*

Read January 22, and February 29, 1829.

MAY I take the liberty of addressing to you, as President of the Royal Society, a request that you will communicate to the Society, if you shall deem them worthy of its notice, the observations on the aurora borealis which I am about to detail in this letter, and which have been made by me at various times under very favourable circumstances, arising out of the very frequent occurrence of the meteor in the latitude of my residence, about  $57^{\circ} 15' N$ .

The immediate occasion of this communication is the interest you have manifested in the subject, in your observations on a luminous belt seen at Rosemorran in Cornwall, 29th September last, published in the *Phil. Mag.* vol. iv. page 453\* ; and likewise a paper by JOHN DALTON, F.R.S., published in the *Phil.*

\* Mr. GILBERT's remarks referred to in the text are as follows :

"The luminous belt which exhibited itself on the evening of September the 29th, in the present year, having been noticed and described from various parts of England, I beg leave to communicate its position as observed at a point very distant from most of the other stations, and therefore likely to be affected by a considerable variation of parallax.

"I was then at Rosemorran, the seat of GEORGE JOHN, Esq., an elevated situation near Penzance, twelve miles from the Land's End. My attention was called to this unusual phænomenon at about eight o'clock. The belt then appeared to rise from the horizon, somewhat to the southward of west, and ascended with a steady light and uniform subtense, of perhaps three degrees, towards the zenith, passing over various stars that were scarcely altered in their appearance, till it reached Alpha Lyræ, then somewhat south of west, and nearly 62 or 63 degrees high. From thence diminishing in brightness it became soon blended with the milky way, and ceased to be distinguishable. The belt seemed exactly similar to a ray of the northern light, except that not the least coruscation was to be observed. Its position could not be much out of the magnetic equator.

"Sir WILLIAM ELFORD, F.R.S. has favoured me with a detail of the appearances seen near Totness, very much agreeing with the above statements."

Trans. 1828, "On the Height of the Aurora Borealis above the Surface of the Earth; particularly of one seen on the 29th of March, 1826." Mr. DALTON in that paper, supposing the same luminous belt was seen on the 29th of March at places distant from each other at the same time, infers its height to have been 100 miles and upwards.

If I shall have occasion to differ widely from Mr. DALTON's conclusions, I beg to do so in terms of high respect for that distinguished individual, whose labours have so much benefited science; and whose opinions I should not have ventured to controvert, had I not possessed peculiar advantages for observation; and had I not made on one occasion an observation which appears decisive of the question of height, as will be afterwards stated.

I do not mean to confine myself, however, to the discussion of that question only, but to communicate several very curious results of the numerous observations I have made, which as far as I am able to ascertain are not yet generally understood among men of science.

I had announced these results in a short paper published in the Edin. Phil. Journ. vol. viii. p. 303, April 1823; they are, "That the aurora borealis has in all cases a determinate arrangement and figure, and follows an invariable order in its appearance and progress;—that the streamers (pencils of rays) of the meteor generally appear first in the north, forming an arch from east to west, having its vertex at the line of the magnetic meridian;—that when this arch is yet only of low elevation, it is of considerable breadth from north to south, having the streamers of which it is composed placed cross-wise in relation to its own line, and all directed towards a point a little south of the zenith;—that the arch moves forward towards the south, contracting its lateral dimensions as it approaches the zenith, and increasing in intensity of light by the shortening of the streamers near the magnetic meridian, and the gradual shifting of the angles, which the streamers near the east and west extremities of the arch make with its own line, till at length these streamers become parallel to that line, and then the arch is seen as a narrow belt,  $3^{\circ}$  or  $4^{\circ}$  only in breadth, stretching across the zenith at right angles to the magnetic meridian;—that it still makes progress southwards; and after it has reached several degrees south of the zenith, again enlarges in breadth, by exhibiting an order of appearances the reverse of that which had attended its progress towards the zenith

from the north ;—and that the only conditions that can explain and reconcile these appearances are, that the pencils of rays (streamers) of the aurora borealis are vertical, or nearly so, and form a deep fringe, which stretches a great way from east to west at right angles to the magnetic meridian, but which is of no great thickness from north to south ; and that the fringe moves southward, preserving its direction at right angles to the magnetic meridian.”

In the paper from whence these results of observation are quoted, I had not entered into a minute detail of any individual observations, but had satisfied myself with a general description of an order in the appearance and progress of the meteor, which I had repeatedly watched ; and a brief account and explanation of some of the apparent irregularities ; hoping this might be sufficient to direct other observers to watch likewise this remarkable order. I had also not distinctly stated, although it was to be inferred from some parts of the description then given, that several successive arches of aurora often appear at the same time within the field of view ; a circumstance of great importance when considered in reference to the numerous observations so industriously collected by Mr. DALTON.

As I am aware the Royal Society justly prefers details of separate observations to any more general descriptions, I shall now give an account of two or three out of several observations I have had opportunity for making since 1823 ; the results of which have been all confirmatory of the above views, with very trifling modifications. Regarding the observations I had previously made, and which opened up to me such peculiar views, I shall only now state, that it was in the autumn of 1814 that I first distinctly observed the ordinary aurora borealis, of long vertically-directed streamers, fairly make its progress from a low northerly situation onward to the zenith, and assume there the form of a narrow luminous belt, at right angles to the magnetic meridian. The discovery inspired me, at the time, with a high degree of satisfaction ; as the apparent general confusion and wild irregularity of the aurora, when viewed in connection with the peculiar circumstance of its most frequently presenting itself in all localities in some determinate relation to the magnetic meridian, admitted now of easy explanation ; and a determinate arrangement and figure, and constant order in the progress of the meteor, to my mind instantly became certain.

On the evening of the 22nd of November, 1825, when returning to my own

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house on foot, at half-past ten o'clock, I saw a fine display of the aurora borealis, accompanied with peculiar circumstances, to be afterwards detailed, which would scarcely leave a doubt respecting the elevation of the region which it occupied above the surface of the earth. These peculiar circumstances arrested my attention, and led me to observe every thing in its appearance and progress. When first seen it had already formed two distinct and separate arches in the north and north-eastern parts of the heavens, the continuity of each of which was only interrupted by a few detached masses of low clouds, coming, with a gentle breeze, slowly from the north, and brightly illuminated by the moon. The most southerly arch approached within about  $25^{\circ}$  of the zenith. It was abruptly terminated at its west extremity, about  $35^{\circ}$  above the horizon; as will be afterwards more particularly described in discussing the question of the height above the surface of the earth. This west abrupt extremity was a little to the north of west. Its east extremity was near the horizon in north-east, nearly as I could judge at the time. The streamers at the vertex of this arch were very short and compact, and parallel to the magnetic meridian. From this point, towards both extremities, the streamers gradually increased in length, and being all directed to a point apparently  $10^{\circ}$  or  $15^{\circ}$  south of the zenith, all formed angles with the general line of the arch, which were more acute in proportion to the distance from the vertex. The arch might be about  $10^{\circ}$  broad, and speedily moved southward, maintaining a parallelism with its first position. Its lateral dimensions became gradually contracted. The streamers near the zenith shortened into dense bundles, like sheaves of light, parallel to the magnetic meridian, and consequently at right angles to the general line of the arch; and those towards the extremities gradually diminished the angles which they made with that line, and approached to a parallelism with it. At length after reaching the zenith, the arch became diminished in breadth to about  $3^{\circ}$  or  $4^{\circ}$ , and coincided in its whole extent with the prime vertical to the magnetic meridian; and the light at its vertex exhibited a nebulous or mottled appearance, and that of the extremities of long streamers or pencils of rays, now parallel to the arch itself. I had no opportunity, upon the present occasion, to witness the enlargement of the breadth again, and the unfolding of the parallel streamers at the vertex, which I had observed in former arches when they got considerably beyond the zenith; for

this arch gradually faded and became extinct, about  $10^{\circ}$  or  $12^{\circ}$  southwards of the zenith.

The other arch of this evening was in its general outline parallel to the one now described, but much lower in the heavens. It also ended abruptly at its western extremity, on a point of the compass much nearer the north than the termination of the other. Its vertex was on the magnetic meridian raised about  $25^{\circ}$  or  $30^{\circ}$  above the horizon; and its eastern extremity ended at the horizon considerably to the eastward of north. In breadth it at first occupied a space of probably  $15^{\circ}$  or  $20^{\circ}$ ; but this could not be correctly estimated, as its northern and southern edges were very irregular and variable, owing to the incessant shortening and lengthening of the streamers of which it was composed, which were nearly vertical, and therefore at right angles to the general direction and line of the arch. This was its first appearance; but it gradually rose in the heavens, and became much enlarged both in length and breadth, increasing the azimuth distance of its extremities from the north, as its vertex rose higher in the heavens, but still remaining abruptly broken short at the western extremity, and lengthening its vertical streamers till its middle part reached an elevation of about  $45^{\circ}$ . In the mean time, however, the streamers near the extremities were gradually changing the angle they made with the line of the arch, constantly directing themselves, whatever position the arch was in, to a point somewhat south of the zenith. After passing the elevation of  $45^{\circ}$ , the streamers again gradually became shorter at the vertex; and those at the extremities going on at the same time to diminish their angle with the line of the arch, the breadth of that became at all points gradually less. This order of appearances went on till this arch had attained nearly the first position and appearance of the one first described, when it rather suddenly became extinct about fifteen minutes after the other had disappeared.

A luminous space near the north point of the magnetic meridian, appeared at this time to promise the formation of a third arch, beginning to show a few streamers; but it soon gradually faded.

On the evening of the 9th of September, 1827, at 11 o'clock, I witnessed a very brilliant, and, with the exception of the one last described, the most instructive aurora borealis which it has fallen to my lot to observe. When first seen, a bright arch of light of various width, and jagged at its edges, stretched

across the heavens from east to west, about  $8^{\circ}$  or  $10^{\circ}$  north of the zenith; its western end resting on a low cloud, and the eastern one descending with a full rich light close to the visible horizon. As this was the first time I had seen such an elevated arch reach to the horizon, that circumstance, and some others, excited my attention particularly. The eastern extremity of the arch was of unusual breadth, about  $20^{\circ}$ , for about the same number of degrees upwards,—seeming to falsify the conclusions, which I had derived from former observations, regarding the thinness of the fringe of vertical rays. Another arch appeared further north, about  $40^{\circ}$  high, and  $20^{\circ}$  or  $25^{\circ}$  broad, composed of streamers all directed to a point south of the zenith. This last had the peculiarity of being suddenly bent downwards, and narrowed in its western part from a point near the magnetic meridian. The horizon near the magnetic meridian was at the same time brightly illuminated under the arches.

A quick progress towards the south became immediately sensible in both arches. The highest arch in a few minutes reached the zenith, and appeared there much narrower and better defined in its edges; and when at this height, its eastern broad end became resolved into two separate and nearly vertical columns of light, the most southerly of which was the continuation of the arch itself, and the most northerly a low column of about  $20^{\circ}$  in height. Each of these columns, when in their progress south they attained their narrowest dimensions, was about  $5^{\circ}$  broad, and the interval which separated them a little more. Here then were two vertical fringes of rays, following each other at a comparatively short interval; or what is rendered more probable, from a circumstance which will be presently stated regarding the more northerly arch, two fringes, preserving parallel planes, and simultaneously moving southward, but the one placed both to the north and the east in relation to the other. This arch was both broader and more irregular in its edges at the zenith than any I had formerly seen, being at least  $6^{\circ}$  in breadth. Its progress southward was very evidently occasioned by the formation of patches, and even very narrow parallel zones of light at its southern edge, sometimes considerably beyond its line, and the extinction of patches at the northern edge\*. Its progress southward was very quick, ranging over  $40^{\circ}$  in about ten minutes. It reached about  $30^{\circ}$  south of the zenith, and then slowly disappeared; previously to which, how-

\* I have often in other cases seen this peculiar manner of progress.

ever, it had much increased in breadth, exhibiting at the same time a renewal of short streamers at its vertex, parallel to the magnetic meridian, and streamers placed angularly to its own line near the extremities, but now increasing their angles in a reversed order, and still directed lengthwise to a point somewhat south of the zenith.

The more northerly arch in the mean time gradually came forward towards the zenith, exhibiting in succession the appearances which I have already described. When it had attained a high elevation, its western bent end became resolved into two abrupt portions of arches, occupying planes parallel with that of the eastern end; but both of them thrown back in relation to the eastern end, and the one in relation to the other, by a distance of  $6^{\circ}$  or  $8^{\circ}$ , in the manner of troops in echelon. The eastern part of this arch had reached very near the zenith, when it suddenly disappeared, and the two westerly fragments gradually faded and became extinct. Both these arches were like the others at right angles to the magnetic meridian.

By this time the light at the northern horizon was greatly enlarged, and soon assumed the form of a new arch of vertical streamers, raised at its centre a few degrees above the horizon; but it did not continue long. After it disappeared, a narrow space at the magnetic meridian again became bright, but the observations were discontinued. On this evening there was a gentle south-westerly breeze, carrying before it a few detached clouds; and an extensive low cloud rested on the tops of the remote mountains in the west. The moon shone brightly; but the light of the meteors literally contended with the power of her beams.

Lest this letter should be extended to too great a length, I shall now only briefly state the observations of one other evening, that of the 29th of September 1828, which may be interesting to you as contemporaneous with your own observation of a luminous arch at Rosemorran.

About ten minutes before eight o'clock I first noticed a remarkable appearance of aurora, and called out some persons then at my house, to witness it with me. At this time the meteor appeared dispersed irregularly into every quarter of the heavens, chiefly in the form of groups of unusually long streamers, all however directed to a point a little south of the zenith; and I had the satisfaction, for the first time, of seeing streamers near the southern as

well as near the northern horizon. The experience derived from former observations taught me to discern immediately an arrangement of these groups, which formed fragments of at least three separate fringes. Observing several groups approaching, from the north, the prime vertical to the magnetic meridian at both its ends, I requested the persons in company with me to watch for a little, when they would see two very brilliant and narrow columns of light at these two quarters, which I pointed out to them. This we all soon witnessed; but the arch over the zenith was not complete, from a deficiency of streamers there. Further observations were not at this time continued. I have since received information that similar appearances were observed at the same time in various parts of this county; and I refer to my own observations of this evening as a proof of the justness of the conclusions, I had formerly arrived at, regarding the peculiar arrangement and progress of the meteor, as well as showing, in conjunction with your observation in Cornwall, that the peculiar matter of the meteor was contemporaneously very active at nearly the extreme north, as well as the extreme south of this Island.

The observations, now briefly detailed, all evidently go to confirm the correctness of the views I had announced in 1823; and the only modifications of the statements then made, now directed by them, are two of a very trifling description. The one, that the point, to which the streamers are directed, is a little more south of the zenith than I had then estimated it. The uncommonly long and brilliant streamers of 9th September 1827, and 29th September 1828, led to this correction. I would now estimate the point at  $15^{\circ}$ , or rather more south of the zenith, instead of  $10^{\circ}$ : but objects so evanescent and unsteady do not admit of preciseness in making such an estimate; and there may yet be an error of  $3^{\circ}$  or  $4^{\circ}$ . The other modification is, that the luminous belt is, at the zenith, sometimes a little broader than I had stated it at its maximum ( $5^{\circ}$ ); and this correction is directed by the appearance of the most southerly arch of 9th September, 1827, which moved southward with unusual rapidity, and appeared about  $6^{\circ}$  broad. There is now likewise an addition to be made to the former statements, which is, that the extremity of the zenith arch sometimes descends to the horizon.

I am fully aware how important it is in the eyes of the Royal Society, that the observations of one individual, of any natural phænomena, should be fully



verified by others ; and it is a fortunate circumstance that those which I have now detailed are almost all incidentally verified by some or other of the many observations collected by Mr. DALTON, although evidently none of these have been made under the impression of those views of the peculiar arrangement of the meteor, which frequent opportunity for observation had opened up to me. I shall briefly point out the verifications. The references are to Mr. DALTON's paper in the Philosophical Transactions. It is unnecessary to refer specifically to the testimonies to three facts, as almost all the observations coincide regarding them. 1st, That the arch of the aurora, when at the zenith, is placed at right angles to the magnetic meridian : 2nd, That there it is only of small breadth : and 3rd, That it moves southwards. None of the observers appear to have had an opportunity for observing the transition of the vertical streamers from a low northerly situation into the zenith arch ; but Messrs. COLDSTREAM and FOGGO at Edinburgh saw, and have well described some of the concluding stages of this transition, and the transformation which the figures and intensity of the lights undergo at the approach to the zenith. The sudden formation of the meteor, only "a few degrees to the north of the zenith," gave them no opportunity for observing the earlier stages. They say ; "When first formed, it" (an arch of silver light) "was a few degrees to the north of the zenith of this place ; the light in the centre was rather diffuse ; its edges were irregular ; and the western limb had, as it were, a plumose appearance. It soon evinced a decided motion towards the south, and in a few minutes reached our zenith. Its edges were now sharply defined, and throughout its whole course it was nearly uniform in appearance and breadth ; the intensity of light in its zenith had increased, while in the same quarter the breadth had considerably diminished." These terms might be interchanged with the description of this last stage of the transition, given by me in 1823.

The enlargement of the breadth of the arch after it has passed considerably to the south of the zenith, is verified by the observer at Newton-Stewart : "It was a bow or arch of silvery light, stretching from east to west, and intersecting the meridian at a few degrees to the southward of the zenith ; after expanding a little in breadth and shifting for a short way further to the south, it disappeared." Unfortunately no notice is taken of the breadth of the arch as seen at Jedburgh,  $30^{\circ}$  and ultimately  $50^{\circ}$  south of the zenith : but the ob-

server there confirms the revival of the flitting streamers at these angles south ; for he says, " waves of light seemed to run along the arch\*."

The contemporaneous existence of two or more arches within the field of view, is fully verified by Mr. SAMUEL MARSHALL, who saw a zenith arch, and another parallel, about  $20^{\circ}$  north of the former, " of less intense light ;" and the northern horizon was luminous. Many of the reports also state, that, contemporaneously with the zenith arch, there were ordinary auroræ in the north.

It should not be overlooked, as a circumstance inferring the fringe-like form

\* I have been desirous, in detailing these verifications, to confine myself chiefly to those found in the observations collected by Mr. DALTON ; but I may be permitted to refer to observations of a fine zenith arch, seen at and near Aberdeen on the 15th of September last, as reported in the Aberdeen Journal of the 17th September. I saw the same arch here at the same time with the observers in Aberdeen. It was here considerably south of the zenith, and extended nearly to the west horizon as well as the east ; and as this place is twenty-five miles west of Aberdeen, this proves the great reach of the arch from east to west. It moved slowly southward, and faded soon after I saw it, in company with three other individuals. The first report in the Aberdeen Journal verifies the increase of breadth of the arch, and the re-appearance of the streamers when it gains a position considerably to the southward. It is stated in the Journal, that the observer in this case made his observations a little to the eastward of Union Bridge. The following are his terms : " On Monday evening last the rare phæ-nomenon of a luminous arch made its appearance in the sky, commencing about nine o'clock, and continuing for about forty or forty-five minutes. When first noticed it presented a very bright zone of white light, in breadth about  $2\frac{1}{2}^{\circ}$ , which it preserved throughout. Its vertex, or most elevated part, was not far to the southward of the zenith ; its direction very nearly at right angles to the magnetic meridian, stretching across the whole heavens from E. to W., and having a slow motion southwards, so that it moved through a space equal to its own breadth in about ten minutes, leaving to the north the constellation Lyra, part of which it had previously included. It terminated at each end near the horizon, behind low masses of stationary clouds, of the species denominated stratus ; its eastern leg was not so straight as the western, but had a sensible inclination towards the N., bending at a very obtuse angle. The evening was clear and calm, the stars bright, Barom. 30.31, Therm.  $48^{\circ}$ . The whole arch was of nearly uniform brightness, except near the extremities, where it became somewhat fainter. There were no sensible motions or coruscations of light ; the larger stars appeared through it, and two shooting stars were seen to fall from neighbouring parts of the sky. About half-past nine it was breaking up slowly, becoming at first broader in the western leg, and then spreading into thin vertically disposed streams of light, which faded gradually away."

The second report is from a station about two miles north of Aberdeen. It is much more brief, and differs from the first, in stating, that " at a quarter past nine the arch was complete from the eastern to the western horizon without intervening clouds." Aberdeen Journal, 17th September, 1828, p. 3.

of the vertical arch, that some reporters, quoted by Mr. DALTON, state the light towards the extremities to be more intense than that at the zenith. In this fringe-like arrangement a line from the eye, directed considerably towards the East or West, would penetrate and collect the light of many parallel streamers; whereas one directed to near the zenith would, on account of their vertical position, penetrate only a few.

I now proceed to the question of the height of the aurora borealis above the surface of the earth. In the paper in the *Edinburgh Philosophical Journal*, 1823, I had inferred, from the bright phosphorescent light of a cloud apparently under an aurora, that they were in contact, or nearly so, with each other. Another similar appearance, of a still more decided character, in the autumn of 1825, but the precise date of which I have not noted, confirmed, in my mind, the justness of the inference. In a dark evening, without moon, an extended mass of clouds stretching along the N. and N.E. quarter, not much raised above the visible horizon, and having a clear sky above it, in which there was playing a fine aurora of vertical streamers, with their lower extremities apparently touching it, was observed giving out at its upper side a fitful but bright white light, more vivid and conspicuous amidst the darkness than if it had been illuminated by the rising moon. Similar clouds in other parts of the horizon exhibited no such light. It was impossible for a spectator to refer the aurora to a distance more remote than that of the mass of clouds; or to believe that the former and the light of the latter were not parts of the same phenomenon. Mr. OTLEY (*Phil. Trans. l. c.*) appears to have witnessed a similar phenomenon. "About 7 P. M. a dense cloud appeared in the horizon to the N.N.W., bounded by a bright line, the rest of the heavens being starry. Presently beams of an aurora began to shoot towards the Great Bear." The appearances now mentioned are of a nature to admit, probably, of frequent verification.

But a combination of circumstances attended the aurora borealis, as seen by me on the 22nd of November 1825, and described above, which seem decisive of this question. On that evening, besides the small detached clouds of the eastern and zenith part of the heavens coming slowly from the north, another of a quite different character extended along the whole western part of the sky to about  $25^{\circ}$  or  $30^{\circ}$  above the horizon. It was one dense sheet or stratum,

comparatively, with the other clouds, very dark below, waved or furrowed from north to south, and cut off at its east side in an apparently straight edge, trending nearly north and south. It was coming on very slowly towards the east, and had before next morning prevailed over the other clouds, covering the heavens, and accompanied with a fresh westerly breeze, after a frosty night which the 22nd of November was. This large sheet of cloud was much more elevated than the small detached ones, as was fully proved by some of the latter being projected, in perspective, on its dark under surface, and there appearing as white masses fully enlightened by the moon.

Now the two arches of aurora of that evening were abruptly terminated at the points where they appeared over the eastern edge of the large cloud; and the abrupt terminations increased their azimuth distances from the north, as the arches came southwards, still appearing, in their new positions, over the east edge of the cloud. The lower extremities of the streamers, which were as long at these terminations as at any other parts of the arches, appeared even in contact with the cloud; and I sometimes conceived that they stretched before its eastern edge: but that part being considerably illuminated by the moon, prevented me from being quite positive. Independently, however, of this uncertainty, the appearances are surely decisive of the fact, that the aurora did not extend into the region occupied by the western cloud; and being seen over it at an angle not much higher than its own, occupied therefore a region of nearly equal elevation above the surface of the earth.

The conclusions to be drawn from these observations harmonize sufficiently with an observation of Capt. PARRY and Lieuts. SHERER and ROSS, who, at Port-Bowen on the 27th of January, 1825, simultaneously saw "a bright ray of the aurora shoot suddenly downward from the general mass of light, and between them and the land, which was then distant only three thousand yards." (Journ. of a Third Voyage under the orders of Capt. WILLIAM PARRY, R.N. F.R.S. 1826.) The conclusions are, that the region occupied by the aurora borealis is immediately above, and contiguous to, the region in which aqueous vapour is forming, or about to be formed, in the shape of clouds. The real height will of course vary with the different states of the atmosphere; I should not have estimated the height of the phosphorescent clouds, above described, at so much as two thousand feet above the surface, or twice the height of some of the

neighbouring hills ; but while the lower ends of the vertical streamers were at this height, their upper might be two or three thousand feet more. I have seen the aurora, however, when the clouds certainly occupied a much more elevated region.

I may now be permitted to make some observations on Mr. DALTON's deductions regarding this question : and here I feel that I ought to be very brief, as that gentleman may be disposed now to review them himself, for which he is infinitely better qualified. He will perhaps now allow, that the more common streamers of the aurora, and the zenith arch, are not distinct, although contemporaneous phænomena, as he seems to suppose ; but that they are exactly the same thing ;—that which is the zenith arch to one set of spectators, becoming resolved into common streamers to other spectators who are placed at some distance, either to the southward or northward of the former. And he may now admit the contemporaneous existence of several parallel arches, even within the same field of view.

Would not the numerous observations made on the 29th of March, 1826, from Edinburgh to Warrington, be more easily explained and rendered consistent with each other, on the supposition, that there were several nearly vertical fringes of the aurora, almost contemporaneously hanging over many lines from Edinburgh to Warrington, at a few thousand feet above the surface of the earth ? Are there not even some circumstances, of the numerous observations, that do not admit of being reconciled, on the supposition that only one arch was seen ? Thus, for instance, the arch over Edinburgh was seen a few degrees north of the zenith, at 8<sup>h</sup> 15<sup>m</sup> P.M. ; that at Jedburgh, 30° south of the zenith, exactly at the same hour. These two observations appear quite at variance with each other, if the same arch was seen by Mr. OTLEY at Keswick, at 8 P.M., a little south of the zenith, and by Mr. HOLDEN, at Whitehaven, at 8<sup>h</sup> 45<sup>m</sup>, 15° south of the zenith :—and the observations at all the four places again become irreconcilable among themselves, if the same arch passed through the zenith, at Kirkby Stephen at 9 P.M. and through the same point at Lancaster at 8 P.M. There are discrepancies also regarding the appearance of the arch itself, in respect of luminousness at its different extremities.

On the other supposition, there would be scarcely any discrepancy. One fringe of streamers might hang over Edinburgh ; another nearly over Jedburgh

and Hawick; at which places the fringe at Edinburgh, forty miles distant, with high intervening land, might well be supposed, if only a few thousand feet above the surface of the earth, not to have been sufficiently bright to excite attention; and accordingly it is not stated, that at Jedburgh or Hawick any northern light was seen. The prolongation of a line a little south of Jedburgh and Hawick, at right angles to the magnetic meridian, would pass very near Dumfries; and the fringe in this line might present in a "sky very clear" "a few streamers, low in the horizon," to Mr. HARRIS at Cockermouth, about thirty miles distant, across the valley of the Solway.

A comparison of the times and elevations leads to the inference, that only one fringe was seen at Cockermouth, Keswick, and Whitehaven; and this fringe, when vertical over Keswick, might present the "splendid light that was observable in the northern horizon" at Kendal, about twenty miles distant. The same fringe or the eastern part of it might, in its progress southward, hang over Kirkby Stephen at 9 P.M.

A fourth distinct fringe might hang over Kendal between 8 and 9 o'clock; and a fifth over Lancaster, twenty miles further, at 8 o'clock;—beyond which, as there are no particulars from Preston, the phenomena cannot be compared with each other.

There may, however, have been more fringes than these: but if there were not, the circumstance would well account for there being no reports of similar arches, seen the same evening, at many intermediate places of note, where the arches reported would be resolved into common streamers, and so excite little attention.

Does there not arise an objection to Mr. DALTON's conclusion, that the arch is one hundred miles high, from the circumstance that the light is often so brilliant at the horizon,—as seen for instance by yourself on the 29th of September, and many others,—at various times? Were the arch one hundred miles high, horizontal rays, coming from the lowest part of it, would enter the atmosphere at nearly six hundred miles from the observer, and would have still about two hundred miles of air to penetrate, after they had come within five miles of the earth; without taking into account the refraction, which would increase the distance considerably. Would not the light, therefore, considering that it is at best but a relatively feeble one, be liable to a great or even total obscura-

tion, near the horizon, if coming from a meteor so high. On the other hand,—on the supposition that the meteor is only a few thousand feet above the surface of the earth,—any objection of this nature almost entirely vanishes.

I shall again briefly return to the more general inquiries.

Several of the observations of Captain PARRY at Port Bowen support other details in this paper. Thus, at that place, where the variation is  $123^{\circ} 22'$  W., and the dip  $88^{\circ} 1'$ , he most frequently saw the meteor in the form of a low arch from about W. to S.E., more frequently bisected by the plane of the magnetic meridian, than that of the true; and he describes the streamers as vertical, or in the plane of the dip. They are here too in the plane of the dip, or nearly so; since in all situations they direct themselves to a point that appears upwards of  $15^{\circ}$  south of the zenith.

Will it not now be admitted as proved by the above observations, and their extensive verifications by so many different persons,—that the aurora borealis always presents itself in definite and very curious relations, to the lines of magnetism, indicated by the needle.

That the streamers, in the direction of their length, coincide with the plane of the dip of the needle, or nearly so; and that each individual streamer is, in fact, parallel to the dipping needle.

That they form a thin fringe, stretching often a great way from E. to W. at right angles to the magnetic meridian.

That the fringe moves away from the N. magnetic pole, by the extinction of streamers at its northern face, and the formation of new ones contiguous to its southern face.

That the invariable regularity of its appearance, as seen by so many observers, when it comes fully within command of the eye, near the zenith, shows the apparent irregularities, when it is seen either more northerly or southerly, to be only optical illusions.

And that the region which it occupies is above and contiguous to that of the clouds, or that in which they are about to form?

I had stated in the paper sent to the Edin. Phil. Journ., that the meteor precedes or accompanies westerly and south-westerly gales; but of this there was unfortunately a misprint of south-easterly for south-westerly. It is, indeed, at the period of the westerly equinoxial gales that it is most frequent; and when

it is seen in winter, it is either immediately before, or during the continuance of, a westerly fresh wind.

I would state, in conclusion, that I have here seen it much more frequently in the form of a light near the northern horizon, than in any other form : and, with the views I have now detailed, entertain, therefore, a suspicion that there is some line, near the shore of the Moray Firth, about thirty miles north, or between this place and that, where it oftener forms a zenith arch than here. This might be worthy of inquiry ; and should it be found to be so, it might be further worthy of inquiry,—whether the circumstance, considering the attendance of the meteor on westerly gales, may not be dependent on the facility with which these gales can traverse into the Moray Firth, through the deep valley of the Caledonian canal. By such inquiries we might ascertain other relations which it may bear to the various thermometrical and hygrometrical states of the atmosphere.

JAMES FARQUHARSON.

*Alford, Aberdeenshire,*

*Dec. 23rd, 1828.*

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POSTSCRIPT.

Since the foregoing pages were written, I had, last evening (December 28th) an opportunity, in company with another person, for observing an aurora borealis, which, from several circumstances attending it, may be worthy of description. It was first observed about half past 6 o'clock, in the form of a very complete arch of pale silvery light, nearly uniform in appearance from end to end, the vertex of which was  $25^{\circ}$  or  $30^{\circ}$  above the N. horizon at the magnetic meridian ; its own breadth  $10^{\circ}$  or  $12^{\circ}$  ; the light nearly steady, and gradually shaded off at both edges. At the same time a much brighter confined light appeared, close to the horizon, at the N. point of the magnetic meridian. The arch of pale light moved southward very slowly ; and after rising  $6^{\circ}$  or  $8^{\circ}$  higher, became resolved into pale flitting streamers, which separated into groups, and soon faded, with the exception of those at the E. end, which continued a considerable time, and approached near the prime vertical to the magnetic meridian before becoming extinct. In the mean time, the light at



the horizon in the N. rose upwards with greater quickness, becoming an arch, and in a few minutes attained the first elevation of the one first described ; but was much more brilliant at its lower side, where the light had a nebulous and nearly uniform appearance, its upper side being shaded off gradually in the form of pale vertical streamers : and as at this part of its progress some of the streamers of the preceding arch remained still visible, one who had witnessed them for the first time in this position might have taken both for parts of the same arch, and so have been liable to draw very false conclusions regarding the arrangement. The second arch soon expired also near the elevation of  $25^{\circ}$  or  $30^{\circ}$  ; but not till a third one had risen from the horizon as it had done, forming a still narrower and more brilliant zone of light. This attained speedily a like ultimate elevation with its immediate predecessor ; and as it came forward to this situation, two more arches equally narrow and brilliant, rose up in succession under it ; so that three low parallel arches were seen, at the same time, in the northern part of the sky, each having its vertex at the magnetic meridian, and each having both its extremities at the horizon. The whole became gradually extinct about 9 o'clock.

These five arches were all unusually flat, extending further both to E. and W. than any I had seen before of equal elevation at the vertex ; seeming thus to indicate that the fringes of streamers were of comparatively low elevation above the surface of the earth. The last four were also unusually narrow from side to side, indicating that the streamers were short.

The evening was calm and frosty, and the sky cloudless, during the continuance of the aurora. Afterwards, about half past 10 o'clock, many low clouds were seen in the region which had been occupied by the aurora, moving rather quickly from the west, the rest of the sky continuing at the time cloudless. The following morning there was a fresh westerly breeze, with the thermometer  $46^{\circ}$  Fahr., which continued through the day. These circumstances lead me to suspect that the aurora was vertical over a valley five or six miles N. of this place, whose longitudinal direction is E. and W. ; and through which I have often seen the clouds driven from the west, with much velocity, at the commencement of a westerly gale, several hours before the gale was felt here, where a lofty ridge of hills shuts up the west side of our valley.

I should add, that, although cloudless, the atmosphere was hazy near the horizon at the time of the aurora ; Alpha Lyræ being much obscured, and the other two stars of the triangle being scarcely visible. Yet the light of the aurora was very bright close to the tops of the hills.

J. F.

*Alford,*  
*December 29th, 1828.*