

XIII. *On the height of the Aurora borealis above the surface of the earth ; particularly one seen on the 29th of March, 1826. By JOHN DALTON, F.R.S.*

Read April 17th, 1828.

APPREHENDING that the Royal Society will favourably receive accounts that have a direct tendency to determine the height of that interesting phænomenon, the Aurora borealis, I have been induced to transmit some observations that were made upon a very remarkable one, which appeared in the evening of the 29th of March, 1826. From some recent observations, an opinion seems to be entertained by some writers, that the aurora is not so high as has generally been estimated ; but it is only from facts and observations such as the following, I conceive, that any near approximation to the true height can be obtained.

The aurora borealis above mentioned, was of a kind very rarely occurring. It assumed the appearance of a rainbow-like arch, stretching across the mid-heaven, at right angles to the magnetic meridian. It was subject to very little change of position for an hour or more, and therefore afforded time to observe the angle of its elevation above the horizon. In the period of five years' observations at Kendal formerly, above one hundred appearances of the aurora occurred to me, and only one of the kind just described. I had not an opportunity of seeing the one which is the subject of this paper, but it was seen here (at Manchester) by a friend of mine about 9 o'clock on his returning home from a visit to me. He did not indeed observe the luminous arch, either from its having vanished, or from the obscurity of our atmosphere ; but he remarked some beams or corruscations in the north-western hemisphere, of a low altitude ; and not having seen an aurora for a long time, he induced the family at home to go out and catch a glimpse of the phænomenon, now much more rarely seen than formerly.

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A few days afterwards I accidentally noticed a paragraph in the Lancaster Gazette describing the luminous arch of the aurora, as well as the accompanying appearances; and as such a striking and unusual phænomenon could not fail to attract general attention, I examined the provincial newspapers and other periodicals of the time, and took occasion soon after to make inquiries personally, or by writing, of such individuals of judgement as had seen the phænomenon in various places near the line of the magnetic meridian. The result was, a collection of a more complete and extensive series of observations than was ever before made, in all probability, towards determining the height of the luminous arch of the aurora.—I shall now proceed to detail some of the particular observations.

The accounts represent the arch to have been seen in places 170 miles distant in a north and south direction, and forty-five miles distant in an east and west direction, comprising an area of seven or eight thousand square miles; but it must have been much more extensively visible, as in most cases the writers of the different accounts describe their situation as central with regard to the phænomenon. It was seen at Edinburgh and Leith, Kelso, Jedbergh, and Hawick in Scotland; at Carlisle, Penrith, Keswick, Cockermouth, and Whitehaven in Cumberland; at Kendal and at Kirkby-Stephen in Westmorland; at Lancaster, Preston, Warrington, and Manchester in Lancashire; and at Doncaster in Yorkshire. Descriptions of the phænomena as seen at most of these places were immediately given in the newspapers of Lancaster, Kendal, Carlisle, Whitehaven, Kelso, &c., and some of these accounts were copied into the London papers soon after.

All the accounts that I have seen from places between Lancaster and Edinburgh, as well as at these two places, agree that a luminous arch was first seen about 8 o'clock in the evening; that it continued without much motion for an hour nearly, and then gradually vanished, leaving the northern sky illuminated as usual after an aurora borealis of the common kind: so that it seems impossible to doubt that the same arch was seen at all the places of observation, and at the same time.

A good description of the phænomenon was published by Messrs. Coldstream and Foggo in the Edinburgh Journal of Science for June 1826: it is as follows:—

“ March 29th. Immediately after the fading of the evening twilight, at 8^h 15^m P.M., a bright luminous ray was seen to rise from the eastern horizon, gradually to extend itself towards the zenith, and thence towards the western horizon, presenting, when completed, the appearance of an arch of silvery light, similar to that seen here on the 19th March, 1825.

“ When first formed it 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 its light in the zenith had increased, while in the same quarter the breadth had considerably diminished.

“ The direction it now had was very nearly at right angles with the magnetic meridian.

“ At $\frac{1}{2}$ past 8, faint beams of the aurora began to rise from the northern horizon, and at one time promised to form a splendid display ; but the corrugations never became very vivid ; they were not rapid in their motions, and did not flit along the horizon.

“ The arch still continued its motion towards the south, and in 15 minutes passed through a space of about 20°. Its southern edge reached a point about 24° or 25° south of the zenith, beyond which it did not go. The light now became gradually fainter, and at length disappeared.

“ Meanwhile the aurora in the north continued to play, but with no increase of vividness. For some minutes, soon after 9 o'clock, we observed broad bands of light, having their longer axes (which generally subtend angles of about 18° or 20°) parallel with the horizon, darting with great velocity across the illuminated space from east to west and from west to east. These formed, ran their course, and vanished in a moment ; they had no vertical motion, but they appeared at various degrees of elevation, never higher however than 30°. Soon after this interesting (and perhaps unusual) display, the beams disappeared, and nothing was left but a diffuse luminousness along the horizon.”

At Jedburgh, Hawick and Kelso, places about forty miles south of Edinburgh, the phænomena were much the same as above, as appears from the

Kelso Chronicle. (See also the London Courier, April 7th, and other of the daily papers.) At Jedburgh the arch is said to have commenced at 8^h 15^m on the W. by S. point of the horizon, to have passed south of the star Aldebaran, between Castor and Pollux, and over Arcturus; its altitude 60° from the S.; waves of light seemed to run along the arch. At 8^h 30^m the whole advanced 20° to the S. At Hawick it was at first 20° S. of the zenith, and at 8^h 40^m it was stationary at 37° S. of the zenith; the arch passed 6° N. of Arcturus, 7° S. of Cor Caroli, 6° N. of Coma Berenices, through the hind foot of Ursa Major, 4° N. of Asellus Borealis, 6° S. of Pollux, through the head of Monoceros, through the three stars in Orion's girdle, and 1° S. of Rigel. From this it would seem that the arch, instead of appearing low in the north from the last-mentioned places, as it must have done if situated only five or even ten miles above the earth's surface, appeared as far to the south of the zenith as at Edinburgh, or rather further. This latter it could not do; and in such circumstances it is reasonable to allow a difference of a few degrees in the estimates of altitudes of arches neither well defined nor absolutely fixed, and possessing several degrees of breadth; but it clearly shows the arch was not low. The author of the Hawick account signs, GIDEON SCOTT.

At Carlisle, seventy-five miles S. of Edinburgh, the phænomena were much the same as in the preceding accounts. See the two weekly newspapers of that city.

About Cockermouth, twenty-five miles S. of Carlisle, I conversed with many persons who had seen the phænomena. One young gentleman, Mr. HARRIS, had committed to paper at the time some notes upon it, with which he favoured me. According to these, he first saw the arch at 7^h 45^m P.M., it extended nearly from the western to the eastern horizon, through the W. part of the head of Orion, over Castor and Pollux, S. of Ursa Major, and ended in Corona Borealis; it continued with little variation in its situation till near 10 o'clock. At first the west end of the arch was most luminous, and finally before it vanished the east end was the most brilliant. The eastern end waxed and waned frequently. The sky was very clear, a few streamers appeared low in the horizon.

At Keswick, about twelve miles east of Cockermouth, the appearance was described as follows, in a letter to me from Mr. OTLEY. This gentleman is

known to the public by an elegant little description of the Lakes and Mountains of the North of England, and is familiar with observations relating to meteorology, and to the angles of elevation of objects. "About 8 P.M., a luminous arch appeared very brilliant; the outside of the curve seemed a little south of the zenith. The eastern end tapered to a point above the horizon; the western end was broader, and lost in a cloud which rested on the mountain. It disappeared about 10 o'clock."

At Whitehaven, one hundred miles from Edinburgh, and a few miles more to the westward, a minute description of the phænomenon was given in one of the newspapers of that place, by Mr. HOLDEN, lecturer on astronomy, who happened to be there at that time. At 8^h 45^m the east leg of the arch covered α Coronæ Borealis, the northern edge of the bow touched Castor near its greatest altitude, and the west leg went over the three small stars marked λ in the head of Orion. The breadth at greatest altitude was 4° 40', but tapered down to the horizon, where it was not more than one-fourth of that breadth. The east leg was 15° north of the east point, and about the same number of degrees south of the zenith; and the west leg was 15° south of the west point. At 9^h 8^m the arch had moved southward, Pollux touched the north of the bow, the west leg extended over α Orionis, and the east leg was still upon α Coronæ Borealis, but this star had been moving in its apparent track by the earth's motion for the space of twenty-three minutes. He saw several small clouds move before and cover portions of it for a few seconds of time.

From Kirkby-Stephen, about forty-five miles east of Whitehaven, a good description of the phænomenon is given in the Westmorland Gazette. The mean breadth of the luminous arch exceeded that of the rainbow, the vertex broader, the extremities narrower, and the light more dense. The arch gradually faded about 10 P.M., having existed nearly two hours. The light was white and transparent. Position at 9 P.M., the arch of a great circle from E. 25° N. through the zenith to W. 25° S. At first the eastern extremity of the arch was near β Herculis, thence it passed the north side of Corona Borealis, through the midst of the seven stars in the Great Bear, over the zenith to the north of Castor, exactly over Bellatrix, after which it contracted to a point in Eridanus just above west. This writer makes no mention of any appearance of the common aurora borealis at the same time.

Accounts from Penrith were much the same as the preceding ones ; but I had no opportunity of seeing any of them.

At Kendal, which is 110 or 115 miles S. of Edinburgh, and very nearly on the same magnetic meridian, (consequently the same part of the arch must have crossed the meridian at both places,) the following is a description of the phænomena as they appeared there, and might have been adopted with very little error, it should seem, for that at Edinburgh or any one of the intervening places, except as to the altitude of the summit of the arch. “ A most magnificent meteor was observed here between 8 and 9 o'clock. The appearance was that of a luminous arch, stretching quite across the heavens. Its direction was that of the magnetic east and west, intersecting the magnetic meridian at right angles. At the same time a splendid light was observable in the northern horizon. This meteor was similar in some particulars to one which appeared a few years ago.” [Query in 1819?] “ The arch itself appeared like two frustums of cones, with the less extremity in the horizon, and their bases meeting in the zenith. The densest parts of the bow were those near the horizon, and the west end the denser of the two.”

The phænomenon was seen at Lancaster, twenty miles S. of Kendal, and 130 miles S. of Edinburgh ; it was described in the next Lancaster Gazette, but without being specific as to the altitude of the centre of the arch. Inquiry having been made of an intelligent medical gentleman who had seen it, he described the luminous arch as extending from east to west across the zenith, the light increasing in intensity from the arch of the zenith to the line of the horizon ; there were those faint corruscations which usually attend an aurora borealis. This was about 8 o'clock ; at 10^h 30^m P.M. there was a luminous appearance along the northern horizon.

The aurora was seen at Preston, twenty miles S. of Lancaster ; but I have not been able to learn the particular appearances at that place. It was also seen at Doncaster in Yorkshire, but I have not noticed any description of its appearance at that place.

At Warrington the luminous arch was seen by a friend of mine, Mr. JOSEPH CROSFIELD, who was so obliging as to give me interesting information on the subject, both verbally and by writing. He saw the arch about 9 o'clock, or between that and 10, in company with two other persons, to whom he pointed

it out at the time. At the first glance he took it for the milky way, but soon discovered his mistake. The direction of the arch was from W.S.W. to E.N.E., passing to the north of the zenith. The western branch was longer and more brilliant. He saw no northern lights at the time, neither did he apprehend the phænomenon was connected with them. On elevating the pole of a celestial globe till the axis passed through a series of angles with the horizon, I desired him to fix upon an elevation which he judged most nearly to coincide with the elevation of the centre of the luminous arch. On examination, the angle was found to be 61° . I then fixed the axis at 70° ; this he was almost certain was too high. When it was fixed at 50° , he was still more certain it was too low.

The aurora was seen at Manchester, as has been stated; but it does not appear to have attracted much attention at this place. I have not been able to trace any account of the phænomena having been seen further south.

These are all the material observations I have collected; from which it must appear that the descriptions every where given evidently apply to the same luminous arch. In proceeding from north to south we find the arch gradually advancing in altitude, always crossing the meridian to the *south* of the zenith, till we arrive about Kendal, at which place it crossed nearly in the zenith, and when at Warrington its culminating was to the *north* of the zenith. It is further remarkable, that in all the places the arch seemed to terminate nearly in the magnetic east and west, or at two opposite points of the horizon; these facts indicated the great height and extension of the arch.

In order to apply the data to calculate the height of the arch, it is evident that observations at the extremities of the magnetic meridians are to be preferred, and those on or near the same meridian, all other circumstances being the same. Unfortunately, the Edinburgh and Hawick observations do not harmonize together: however, those at Jedburgh, a place nearly of the same latitude as Hawick, seem to show that both the others are wrong, or rather perhaps, that they had not been cotemporary with each other and the rest of the observations. The Hawick altitude is probably too low, and that at Edinburgh considerably too high.

In this uncertainty we may be allowed to take the observations at Whitehaven and Warrington as guides. Those places are very nearly on the same magnetic meridian; they are distant eighty-three miles, giving an extensive

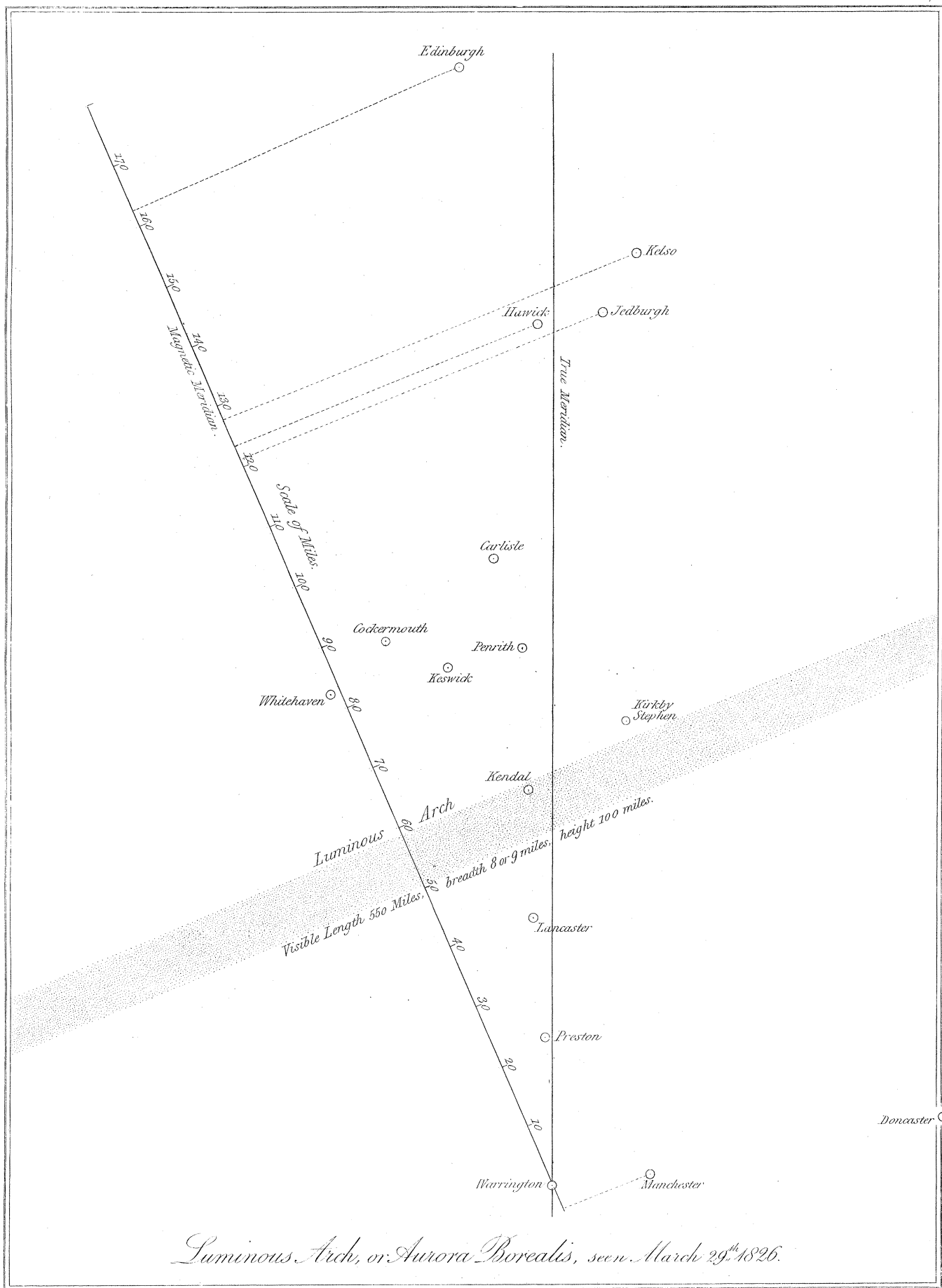
base : the observations were nearly cotemporary, and made on the same part of the arch, the altitude at Whitehaven being 75° from the south, and that at Warrington 61° from the north. From these data, I find the height of the arch very nearly one hundred miles above the earth's surface, and its position vertical about Kendal and Kirkby-Stephen, which accords well with the observations at those places. This conclusion is corroborated by the observations at Jedburgh and Warrington, where, if we take the angles of elevation at 60° and 61° respectively, and the distance on the magnetic meridian 120 miles, the height will be found between 100 and 110 miles. But, lastly, if we assume the angle at Edinburgh to be correct at 65° , and that at Warrington at 61° , the height comes out 150 or 160 miles, and its position vertical about Carlisle, which is in opposition to the general tenor of the rest of the observations.

As for the heights of the streamers or vertical beams seen low in the north, we have no sufficient data for determining it. But it is evident that the beams which were seen low at Edinburgh were the same as those seen still lower at Cockermouth, Kendal, Lancaster, and Manchester, at which last place the angle was about 10° as my informant says. Now an object elevated about 25° from the north at Edinburgh would apparently be 10° or 12° at Manchester, if its real height were about one hundred miles above the earth's surface.

On the whole, I think it is fairly to be inferred that the height of the arch could not differ much from one hundred miles ; and that its breadth would be eight or nine miles, and its visible length in an east and west direction, from any one place, would be about 550 miles. (See the accompanying figure.)

Observations on other Auroræ.

The height of a luminous arch calculated by the late Mr. CAVENDISH, F.R.S. in the Phil. Trans. for 1790, is entitled to notice. It was found to be betwixt fifty-two and seventy-one miles. The observations, however, were made at too small a distance from each other to admit of precision. A base of at least forty or fifty miles seems necessary, where the object to be measured is generally neither steady nor well defined.



The luminous arch seen at Keswick and Kendal by Mr. CROSTHWAITE and myself, on February 15th, 1793, was calculated to be 150 miles high ; but this was from a base of only twenty-two miles. (See my Meteorological Observations and Essays, page 69.)

Dr. THOMSON has given a brief history of the Aurora borealis in the Annals of Philosophy for 1814, Vol. IV. He has copied a table from BERGMAN, being estimates of the heights of about thirty auroræ observed during the last century, calculated from observations made by different persons in various places. According to these results, the auroræ would seem to be of variable heights, from 130 to 1000 or more miles. The places of observation are often unsuitably situated ; and the data from which the calculations were made not being given, I apprehend the great differences in the heights arise more from defects in the observations than from real differences.

In the same volume Mr. LONGMIRE gives a description of a luminous arch seen at Troutbeck near Kendal, on the 11th of September, 1814. It was similar to that above described, and was most extensively seen : namely, at Glasgow, Dumfries, and Annan in Scotland ; at Dublin and Newry in Ireland ; and at Whitehaven, Carlisle, Kendal, Lancaster, Warrington, and Liverpool in England. It was accompanied with the usual appearances of the aurora borealis, or streamers distant in the north. The observations are insufficient for calculating the height. I find in my journal the aurora was noticed at Manchester that evening, but no particulars are given. Mr. LONGMIRE mentions a similar arch seen at Kendal and Dublin on the 17th of April the same year. An aurora was seen in London at the same time. (Annals of Philosophy, Vol. III. p. 400.)

1819, October 17th.—A remarkable aurora borealis was seen this evening in very distant parts of England and Scotland. Mr. OTLEY of Keswick first drew my attention to this, by communicating the notes he made at the time upon it, on the occasion when he favoured me with his remarks upon that of the 29th of March, 1826. After which I collected such other accounts as I could meet with from the journals of the time. The series of observations is as follows :—

Annals of Philosophy, Vol. XIV. p. 472. Account from Newton-Stewart, (Scotland,) October 18th.—“ A singular and beautiful phænomenon appeared

in our atmosphere here last night (17th), about 8 o'clock : it was a bow or arch of silvery light stretching from east to west, and intersecting the hemisphere [meridian] at a few degrees to the southward of the zenith. After it had remained very bright for twenty minutes or so, dark blanks were first observed to take place here and there, and then, after expanding a little in breadth and shifting for a short way further to the southward, it disappeared. Some time before its appearance the atmosphere had been very cloudy ; but when it was formed the sky was free from clouds, except towards the horizon to the westward and northward, where they hung very dark and heavy.—It was strikingly different from any of the usual forms of the boreal lights, which too were seen very vivid in the course of the evening.”

Keswick. Mr. OTLEY's account :—“ About 7 P.M. (the 17th), 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. About 8 o'clock a luminous arch extended from west to east ; the crown of the arch at first appeared to me a little to the north of the zenith, and after some time to the south of it, and again more northerly before it disappeared, which it did suddenly, a few minutes after 9 o'clock.”

Manchester.—I have an account in my journal of an aurora seen here the same evening, but no particulars are given.

London.—The aurora was seen in and about London the same evening. (See pages 478 and 480, Vol. XIV. *Annals of Philosophy*.)

Gosport.—In the same volume of *Annals*, page 395, there is an account of the same aurora as seen at Gosport Observatory, Hampshire, on that evening by Dr. BURNEY. The following is an extract : “ On the 17th instant, at 7 P.M. a light about 30° on either side of the magnetic north point appeared in the shape of a luminous arch whose apex was 18° above the horizon.” He then describes several beams of the common aurora which successively appeared and traversed about for a time chiefly within the arch, and then vanished and were succeeded by others. After which, he adds : “ Soon after this (9 o'clock) the luminous arch in the northern hemisphere entirely disappeared, and some haze collected near the horizon.”

Gosport and Keswick are very nearly under the same magnetic meridian, and 265 miles distant. Newton-Stewart is N.W. by W. of Keswick, distant

about sixty-five miles, but only thirty-five miles in a meridional direction. Now I imagine it will be allowed that an extraordinary luminous arch seen at Newton-Stewart to cross the meridian a few degrees south of the zenith, and to continue from 8 to near 9 o'clock, nearly in that position, must have been the arch seen at Keswick at the same time to cross the meridian in like manner from east to west, and to pass nearly through the zenith. It may well be supposed, then, that this arch crossing through the zenith at Keswick would have a very diminished altitude if seen at Gosport, 265 miles south. From the account I have extracted, it appears that a luminous arch was seen there at the same time it was seen at the other places, and crossing the meridian at right angles, only its altitude 18° from the north, instead of being in the zenith, as at Keswick, or a few degrees south of it, as seen in Scotland. And further, the arch vanished at all the places at the same time. It scarcely admits of doubt, then, that these arches were all one and the same. By calculation from the data at Gosport and Keswick, I find the height of the arch above Keswick to be 100 or 102 miles ; from which the angle of elevation from Newton-Stewart must have been 71° from the south, or the zenith distance of the arch 19° .

A luminous arch was seen at Kendal on the 27th of December, 1827, of which my friend Samuel MARSHALL was so good as to write me a circumstantial account. It was first seen at ten minutes past 6 in the evening, being an arch between the magnetic east and west, and passing through the zenith. It was broadest in the zenith, and it was more condensed in the eastern extremity than in the western. Another parallel arch appeared about 20° north of the former, of rather less intense light ; and the northern horizon was luminous as usual on such occasions. After ten minutes or more, the arches advanced each of them to the south 20° with their centres. The appearance lasted about half an hour. A few streamers were seen in the east, which moved slowly northward. Mr. MARSHALL thinks the appearance would have been splendid if the moon had not shone at the time : a halo round the moon vanished when the bow approached it. I observed a halo round the moon at Manchester that evening.

Mr. BUCHAN, a gentleman accustomed to meteorological observations, had mentioned his having seen a similar arch at Manchester on that evening ; but apprehending it might only have been a local phænomenon, I did not inquire

particulars till I received the above account from Kendal. Mr. BUCHAN informs me he saw a luminous arch that evening, about 9 o'clock ; the arch was highest to the west of the meridian, and its altitude was very nearly the same as the north pole, just under which it passed ; he estimates it at 53° , and thinks it could not be above 1° more or less. As this observation was not contemporary with that at Kendal, nothing certain can be deduced from them, but it may not be amiss to observe that an object in the zenith at Kendal, and elevated 53° from the north at Manchester, must be nearly one hundred miles high.

The results of this series of additional observations agreeing so nearly with that of the 29th of March, 1826, I am induced to believe that these luminous arches of the aurora which occasionally appear, stretching from east to west, are all of the same height, and that height about one hundred miles. What length the upright beams,—or to speak more properly, those parallel to the dipping needle,—may be, which are the ordinary forms of the aurora, we have not observations to determine. Whether those beams arise above the arches as from a base, or whether they descend below, as if appended to the arches, we cannot absolutely determine. It is remarkable that the arches and beams should rarely, if ever, be seen cognate or in juxta position, but always in parts of the heavens at a considerable distance from each other.

Manchester,
March 18, 1828.

POSTSCRIPT.

Query, Are the parallel bands usually about 20 degrees asunder ? If so, their distance from each other will be about thirty-six miles.