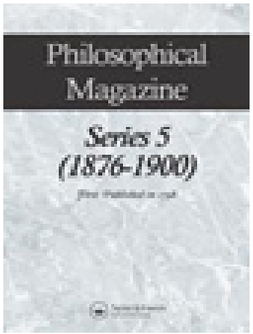

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XLVII. The auroral beam of November 17, 1882

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A second unknown resistance may now be substituted and measured as before, simply by altering the resistance of R, with the certainty that when there is a balance the current is of the same strength as in the former case. The resistance nx remains unchanged throughout. It is of course necessary so to choose the values of a, n, and E that x may be greater than the resistance to be measured; and it is generally desirable that the resistance of the whole bridge should be made as high as conveniently possible.

The great advantage of this method over others that suggest themselves lies in the fact that, since it is never necessary to close the circuit for more than a moment, the electromotive force and resistance of the battery remain sensibly constant during a long course of experiments.

XLVII. *The Auroral Beam of November* 17, 1882.

By J. Rand Capron, *F.R.A.S., F.M.S.**

[Plate VII.]

NOVEMBER last (1882) was remarkable for the great auroral storm, or, rather, series of storms, which prevailed over a considerable portion of the globe during the latter half of that month.

Accounts of brilliant displays from the Shetland Islands, at Edinburgh, a great number of localities in England, Rome, and Florence soon made their appearance in the public prints; and to these later on were added others from America, California, Spain, Sweden, Belgium, the Netherlands, and other countries.

Continuous auroræ were seen at Trondhjem from the 12th to the 18th of the month; and I traced almost incessant displays in these latitudes from the 13th to the 24th at least—the motions of the telegraph-needles acquainting us that auroræ were not only present when actually visible, but by day and during clouded nights.

Also accompanying these were considerable groups of solar spots, one the largest ever seen at Greenwich, and a widespread disturbance by earth-currents of State telegraphic communication in nearly all the countries above mentioned. It was during one of these storms that, in the south of England and the adjacent parts of France and Belgium, a phenomenon was seen which, though apparently not without precedent in the annals of auroræ, was at least of a rare and striking character.

* Communicated by the Author.

About 6 P.M., while the aurora was fitfully blazing in the north, north-east, and north-western sky, in the east there rose from the horizon a long beam of detached bright light, which, apparently lengthening as it advanced, crossed rapidly the southern horizon in front of or near the moon, and then sank in the west, shortening in length as it did so. The light emitted from it was described by one observer as of a glowing pearly white; and the general effect of this huge shining mass sailing majestically across the sky, even upon those accustomed to kindred phenomena, was at least one of wonder and surprise, while in the less experienced in such matters it created a feeling of absolute awe. Indeed to such an extent in some instances did this latter emotion prevail, that two labourers in my neighbourhood, who separately witnessed it, thought "that surely the world was coming to an end."

In this general description of the "beam" of the 17th of November, I may add I have advisedly preferred to use the term "beam" (the "trabs" of Musschenbroëck, an oblong track parallel to the horizon) as a definition of the object, because in speaking of auroral rays and beams it is generally understood that the former are the spreading fixed shafts (sagittæ) which shoot from the arches or horizon towards the zenith, while the latter term is applied to the bright clouds passing at right angles to the former. Good examples of these were observed at Guildford on February 4, 1874, and are figured in 'Auroræ,' plate 6. Having regard to the almost unique nature of the phenomenon, it seemed to me a desirable thing to gather together the published accounts of its appearance, and to endeavour to trace something of its history more in detail and more precisely than they singly afford.

In a few of the public prints (notably in 'Nature') a number of interesting (and doubtless accurate, so far as the suddenness of the apparition would admit of) observations are recorded; but, on the other hand, it is somewhat strange that the scientific journals in general contain but little, if any, notice of it; and as to newspapers, while the 'Standard' and some few others contain scattered accounts, the 'Times' (probably from a want of due appreciation of the importance of the subject) published two letters only out of a "great number" it stated it had received. Regretting this, and using to the best of my ability the materials I have found at my command, I have drawn up a schedule of twenty-six observations at home and abroad, showing at one glance the prominent features in each observation and giving the authorities, that those so disposed may consult them for further or more exact details. They are as follows:—

Particulars of Passage of Auroral "beam" of 17th November, 1882. (Moon's position at Guildown, Guildford, at 6.14 P.M., R.A. 21h 12m 0s, Dec. S. 10° 35′ 0″.)

No.	Reference.	Observer's name.	Station.	Time.	Latitude.	Longitude.	Time of flight.	Length.	Breadth.	Direction of flight.	Observer's notes.
					Observations where stated to pass *above* the Moon.						
				h m	° ′ ″	° ′ ″					
1.	'Standard' paper.	Railway signalman.	Sidmouth ...	6 8	50 42 0 N.	3 15 0 W.	.....	.....	.....	.....	Overhead, accompanied by much telegraphic disturbance.
2.	* Nature, vol. xxvii. pp. 84, 149.	J. R. Capron.	Guildown, Guildford.	Soon after 6.	51 13 39 N.	0 28 47 W.	Little more than 1 minute.	.....	.....	E. to W. nearly.	About 2° above Moon, centre to centre; altitude of Moon above horizon 28½°; spindle-shaped: spectroscopic observation.
3.	83.	Astronomer Royal.	Greenwich...	6 4	51 28 0 N.	0 0 0 W.	About 2 minutes.	20°	.....	E.N.E. to W.	Passed nearly along a parallel of declination. A little *above* the Moon; Mr. Maunder adds, "quite close above the Moon."
					Observations where stated to pass *across* the Moon.						
4.	Idem, pp. 100, 141, 412.	A. Batson ...	Ramsbury (Hungerford)	6 2	51 25 0 N.	1 30 0 W.	.....	15°	3°	.....	Torpedo-like. Passed exactly across Moon's disk. Moon's position at Ramsbury:— R.A. 21h 12m 56s, N.P.D. 100° 35′ 7″.

* To save repetition, in all cases where page numbers only are given vol. xxvii. of 'Nature' (in which the phenomenon is reported) is understood.

5.	Idem, p. 87.	John J. Dobson.	Old Windsor.	6	5	51 29 0 N.	0 38 0 W.	50 sec.	30°	4°	E. to W.	Fish torpedo, or weaver's shuttle. Rose a little south of Aldebaran and slid along at same N.P.D., across face of Moon and disappeared in W. under Altair.
6.	Idem, p. 141.	E. Pollock ...	Lincoln's-Inn Fields.	6	0	51 31 0 N.	0 6 0 W.	Less than ½ min.	.....	.....	E. to W.	*Across* face of the Moon. Moon's diameter above and below.
7.	'Standard.'	J. Woodruff.	Broxbourne (Hertford).	?		51 39 0 N.	0 1 0 W.	.....	.....	.....	.....	Passed *across* the Moon.
8.	Nature, p. 87.	Hubert Airy.	Woodbridge.	6	7	32 6 0 N.	1 20 0 E.	About 1 min.	40°	5°	E. to W.	Exactly *across* the Moon; rose vertically below the Pleiades, like a cigar-ship.
9.	Letter to Roy. Astr. Soc.	Wm. Munro.	Chatham ...	6	5	51 23 0 N.	0 35 0 E.	$1^m\ 30^s$	30°	3°	N.E. to S.W.	Snowy disk of cloud sailing edgewise; dark nucleus $3° \times 2°$; *over* (across) Moon's disk (moon shining through it).
						Observations where *stated* to pass *below* the Moon.						
10.	Nature, p. 84.	Joseph Clark.	Street, Somerset.	Soon after 6.		51 7 0 N.	2 43 0 W.	Less than 4 min.	.....	.....	S.E. to S.W.	*South* of Moon, bar of yellowish light, "dark something" before the bar and dark streak where it passed. Same position as arch at Leeds. (Observation 22.)
11.	Idem, pp. 86, 100, 338.	S. H. Saxby.	E. Clevedon, Somerset.	6	15	51 26 0 N.	2 52 0 W.	80 sec.	35°	3°	E. to W.	Rather *below* Moon. Altitude on meridian about 22°; pale yellow-white. Trajectory much flatter than the stars.
12.	Idem, p. 85.	T. G. Elger...	Hempston, Bedford.	6	5	52 7 0 N.	0 27 0 W.	About 6 sec.	20°	5°	S.E. to S.W.	Lenticular; axis parallel to horizon, passed *below* Moon. Spectroscopic observation of rosy streamers.

N.B. Where seconds are not given the latitudes and longitudes are only approximate.

Table (*continued*).

No.	Reference.	Observer's name.	Station.	Time.	Latitude.	Longitude.	Time of flight.	Length.	Breadth.	Direction of flight.	Observer's notes.
					Observations where *stated* to pass *below* the Moon (*continued*).						
13.	'Standard.'	Thos. Woodruff.	St. Ives, Huntingdon.	?	52° 22′ 0″ N.	0° 17′ 0″ W.	.....	.....	.....	.....	5° or 6° *below* Moon.
14.	Nature, pp. 87, 146, 365, 434.	H. D. Taylor.	Heworth, York.	6 4	53 50 0 N.	1 56 0 W.	¾ min.	30°	.....	S.E. to S.W.	About 30° altitude on magnetic meridian. *Under* the Moon about 6° (?) centre to centre.
15.	Idem, p. 85.	A. M. Worthington.	Bristol	6 3	51 26 0 N.	2 35 0 W.	Hardly 1 min.	27°	1°	E. to W	*Under* Moon; rather less than three times Moon's diameter.
16.	Idem, p. 99.	H. McLeod.	Cooper's Hill.	?	51 25 57 N.	0 34 5 W.	.....	.....	.....	to S.W.	Just *below* Moon. One observer thinks upper edge grazed lower edge of Moon.
					Observations where an estimated altitude independent of position with regard to Moon is given.						
17.	Idem, p. 86.	E. Brown ...	Cirencester...	Just after 6.	51 43 0 N.	1 58 0 W.	.....	.....	.....	.....	Altitude about 30°. Shaft of intense white light.
18.	Idem, p. 87.	A. S. P.	Cambridge...	6 5	52 13 0 N.	0 7 0 E.	Less than 1 min.	.....	.....	Due E. to S.S.W.	Spindle-shaped. Subtended visual angle about 20°.
19.	'Times' paper.	C. M. Ramus.	Rye, Sussex.	About 6	50 57 0 N.	0 43 0 W.	2 min.	90°	.....	E. to W.	About 50° above horizon; described as a cometary body.
					Observations where no altitude is given.						
20.	Idem	J. P. K.....	Wimbledon, Surrey.	6 5	51 25 0 N.	0 10 0 W.	2 min.	.....	.....	E. to W.	Shaped like a torpedo; glow like that of an electrically excited vacuum.
21.	Nature, p. 100.	C. J. Taylor.	Wandsworth. Ilford, Essex.	6 4	50 51 0 N.	0 37 0 E.	Less than 1 min.	20°	2°	E. to W.	

					Observations of other beams or arches.						
22.	Idem, p. 84.	J. E. Clark.	Leeds	5 25	53 47 0 N.	1 32 0 W.	1 min.	2°	1½°	W.S.W. to E.S.E.	Just *over* the Moon, a green arch.
23.	Idem, p. 141.	J. R. Clapham.	Clapham, Lancaster.	5 6	54 7 0 N.	2 22 0 W.	.....	.....	.....	E. to W.	Stationary arc 30° to 40° above horizon and *above* Moon.
					Foreign observations.						
24.	Idem, p. 296.	Prof. Oudemans.	Utrecht	6 23 (local) 6 2 30 G.M.T.	52 6 0 N.	5 6 0 E.	2 min.	.....	3°	E. to W.	Feather-like comet, rose just before Aldebaran, above Saturn, through Pegasus quadrant, and S. of three Eagle Stars. When 90° length attained, separated and division formed 10°×½°; horizontal direction E. 20° N. to W. 20° S.
25.	Idem	P. Zeeman ...	Zonnemaire (Zierikree)	6 20 (local).	51 42 0 N.	3 56 0 E.	.....	.....	.....	N. of E. to S.W.	Horizontal bearing E. 20° N. to W. 20° S., through Aldebaran and α Pegasi.
26.	*Ciel et Terre*, no. 20, p. 465.	Prof. Prignon	Péruwelz (Hainault).	6 30 (local).	50 25 0 N.	3 35 0 E.	1 min.	80°–100°	4°–5°	N.E. to S.W.	"Forme de fuseau." Passed near the zenith.
27.	Idem, p. 466.	M. Thooris.	Bruges	.....	51 12 0 N.	3 13 0 E.	Less than 2 min.	30°–35°	4°–5°	N.E. to N.W.	Like comet's tail. Axis darker than the rest. Across zenith.
28.	Idem	Editor	Bruxelles ...	6 20 (local).	50 51 0 N.	4 20 0 E.	.....	.....	.....	E. to W.	Appeared between *i* Aurigæ and α Tauri, passed a little N. of zenith, and descended between β and χ Ophiuchi; obscure "noyau."

N.B. Where seconds are not given the latitudes and longitudes are only approximate.

In the foregoing schedule of particulars I have not given the dates of the 'Standard' and 'Times' newspapers; but the letters appeared within a few days of the 17th.

Mr. Munro's letter (obs. 9) was addressed to the Secretary of the Royal Astronomical Society (to whom I am indebted for its loan), and contains a good deal of interesting matter in connexion with the "beam" beyond the particulars abstracted.

A primary question which presents itself in the subject is, whether the "beam" was really and truly a part of the auroral display, or a "meteor," "meteoroid," "cometary body," or something allied to any of these in contradistinction to an auroral beam. Independently of other considerations, two spectroscopic observations which have been recorded put, I think, this point well beyond a doubt. In my own case (obs. 2) I was using the spectroscope (a large Browning direct-vision one) upon the aurora northwards, but, accidentally turning and seeing the beam, I at once applied the instrument to it. The spectrum (not to be found on the adjacent sky) was observed to consist of the well-known principal citron auroral line (W.L. 5569), and a faint greenish-white continuous spectrum extending from about D to F. No other bright line than the principal one was visible; and the continuous spectrum showed no trace whatever of Fraunhofer dark lines—indicating an absence of solar reflected light. The second observation was made by Mr. F. W. Cory, of Buckhurst Hill, Essex, who in a letter to 'Knowledge' (vol. iii. no. 62) says:—"I think there can be no doubt in regard to the connexion between the torpedo-shaped body that was seen on November 17 at $6^h\ 5^m$ P.M. and the aurora, as the spectroscopic examination gave the same line for both; and this was situated between D and E in the spectrum, but nearer the former." That the aurora of the 17th was of the same spectroscopic character with previously examined ones is shown by the observations of (1) Mr. Cory, as above mentioned; (2) my own, I finding in the brighter parts the citron line, and a few others indistinctly shown; (3) Mr. T. G. Elger's (obs. 12), who in the pink portions of the aurora found the usual red and green lines; (4) Dr. Wm. Roxburgh, of Bournemouth, who, in a letter to Prof. Piazzi Smyth, states he found five lines agreeing in position with those given by Prof. Smyth in his plate of the auroral spectrum figured in the 'Royal Observatory of Edinburgh Observations,' vol. xiii.; and (5) Mr. Henry Robinson ('Nature' p. 85), who saw the green line and some others less distinctly in the blue and violet.

Having disposed of this preliminary point, we will now turn to the other incidents of the "beam" detailed in the twenty-six

observations. And, first, (column 4), **time** of its appearance. Owing no doubt to the sudden and unexpected advent of the object, the times recorded are evidently not very certain, and, with the exception perhaps of the Greenwich and some of the foreign observations, are doubtless neither chronometer nor clock time. Many do not profess to be exact; and we are not generally told whether they are Greenwich or local, though probably they are the former. I think, however, they are sufficiently near to enable us to identify observations 1 to 21 and 24 to 28 as all applying to the same phenomenon. For any other purpose the recorded times do not seem of much practical use. Secondly, **time occupied in transit** (7th column). This is also involved in some obscurity. One observer (obs. 12) gives so short a time as "about 6 seconds," while another (obs. 10) extends the time to a length of "less than 4 minutes;" and between these rates we get estimates mostly of 1 and 2 minutes, accompanied by such qualifying expressions as "less," "about," &c. A mean of eighteen observations is found to be 1 minute 15 seconds. As to the longer periods, we know by the experience of counting beats by clock or chronometer that the estimate of time by observers not so accustomed is usually an overrate; and I think we may consider this to have been the case in these instances. Thirdly, as to apparent **length** and **breadth** of the object (columns 8 and 9). These of course, as with the time occupied in transit, would vary with the position of the observer; and at places situated more southward the object would have been seen of greater length and breadth than when seen from the north, while east and west positions would get foreshortened effects. Perspective would come into play with the position of the beam in the sky, most observers agreeing that it lengthened out as it neared the zenith, though one (Mr. Batson, obs. 4) thought it contracted as it passed across the moon. The observations, however, are really not conformable; and though three 30° make their appearance, the observers (obs. 5, 9, 14) differ in position and in their time of transit estimates. The estimated lengths, as might be expected, differ more than the breadths. Perhaps the two most inconsistent records are the Péruwelz (obs. 26) and the Bruges (obs. 27) observations with the same breadth but so great a difference in length. A mean of eleven observations for length (excluding the Rye and Péruwelz observations) and of nine observations for breadth gives $27° \times 3\frac{1}{3}°$ as a general idea of the beam's apparent size.

Column 10 brings us to the **direction of flight**. In this case we have more actually accordant observations, inasmuch as all agree in general terms upon a flight from an east to a

west quarter of the horizon. The exact direction, however, is (doubtless for the same reasons which affected the time of appearance, time of flight, and size) but rarely given. In some instances qualifying words are used, such as (in my own observation) "nearly." In others, degrees of deviation from the cardinal points are given; and generally there seems a tendency on the part of observers situated northwards to place the rising and setting points southwards, and the reverse with the southern observers; but beyond this the deviation from the E. and W. points respectively, according to the observer's station, is not very regularly indicated. The observers have not stated whether astronomical or magnetic points are recorded; probably in most cases the former are intended. The only instances where precise figures are given are those of the observations at Utrecht and Zonnemaire, in which, after stating the direction of flight in a general way as E. to W. and N. of E. to S.W., both observers agree in fixing upon E. 20° N. to W. 20° S. as the horizontal direction. Having thus ascertained as nearly as we may the hour of appearance, time and direction of flight, and size of the beam, its particulars may be summed up as follows:—

(*a*) Character, auroral.
(*b*) Time of appearance, a little after 6 P.M.
(*c*) Time of flight, about 75 seconds.
(*d*) Apparent approximate length and breadth, $27° \times 3\frac{1}{3}°$.
(*e*) Direction of flight, magnetic E. to W.

We will now gather from the observers some idea of its general appearance to the eye. The descriptions recorded are sometimes peculiar in expression; but all fairly represent a similar form. Among them are:—"spindle-shaped," "forme de fuseau," "torpedo or weaver's-shuttle," "cigar-ship," "lenticular," and a "comet's-tail," while one observer not inaptly compares it to the well-known fusiform nebula in Andromeda. For descriptive colour, those selected seem to be "white," "pearly white," "greenish white," and "yellow white," it being somewhat significant of the beam's specific character that the last two combined will represent the locus of the principal aurora line indicated in Prof. Piazzi Smyth's beautiful colour plate in 'Madeira Spectroscopic' by the tint "citron." The *quality* of the light is somewhat variously described in such terms as "glowing," "shining," and "phosphorescent;" and one observer (obs. 20) compared it to an electric glow *in vacuo*; and certainly to me it was not at all unlike the glow of a carbon Geissler tube. The Utrecht observer (obs. 24) speaks of it as "feathery;" but to me and most other English observers the edges were fairly well defined. I thought, how-

ever, I detected a sort of broken and clouded structure, difficult to describe except as being something like what certain forms of cumulo-cirri would appear if illuminated by Balmain paint. Mr. Worthington (obs. 15) noticed it had the ends of a rough splintered appearance. Mr. Batson (obs. 4) says that the object when nearest presented throughout its length (but rather below than above) a remarkable "boiling" appearance (as seeds in a capsule), while the edges appeared smooth and quiet. I did not myself observe this. One curious feature (noticed particularly abroad) was a sort of nucleus, or rather central dulness.

Prof. Oudemans (obs. 24) remarks that when 90° length was obtained the beam separated and a division (longitudinal I presume) was formed $10° \times \frac{1}{2}°$; while in the Bruxelles observation we find "Quand elle eu déjà disparu en partie derrière l'horizon, elle présenta un noyau plus obscur, comme elle l'avait fait à l'horizon oriental." Mr. Munro (obs. 9) is the only English observer who appears to have noticed this feature; and he speaks of a "dark nucleus" about 3° transverse diameter and 2° conjugate—his position, it may be noted, like the foreign ones, being to the east of Greenwich. Mr. Munro further describes the beam as like the edge view of a luminous quoit, its diameter being parallel to the horizon.

This definition is well supported by the circumstances of the nucleus being mostly observed where the beam, as in Belgium, passed overhead, and by the wider breadth (4° to 5°) assigned to it there, at the same time that most English observers saw no nucleus, and estimated, on the whole, the breadth as decidedly smaller. This would give a figure, as seen in the zenith, of a ring much pulled out with a central opening (the nucleus being described as a dark one or a division), while as viewed at an angle the short diameter would be less and the central nucleus lost. The form thus obtained (a pulled-out ring) is what one might anticipate of an elastic gaseous or fluid-like body flying at considerable speed through a resisting medium.

Among the incidents mentioned exceptionally may be noticed Mr. Saxby's (obs. 11) observation of a second beam 70° northward, which appeared as the principal one approached the W. horizon; and also some observations reminding one of the dark-shadow or contrast tint seen near the end of the tail of the recent Great comet. These are as follows:—(1) Mr. Joseph Clark (obs. 10) observed a "dark something" before the "bar" which seemed to indicate the path it would take, and also a dark streak where it passed. (2) Major J. Herschel ('Nature,' p. 87), in quoting from a correspondent's letter to him, says "it left a black cloud of its own shape,

which disappeared in a few seconds." (3) Mr. Dobson (obs. 5) says it was preceded and followed by "a strong black margin." I saw nothing like any of these myself, though I had an impression the beam was following some definite path. Other observations (if made) would be interesting on the point whether these appearances were real or subjective impressions.

Turning our attention now to the combined questions of the object's position, direction of flight, and height above the earth's surface, we already find in print some opinions regarding these. Mr. Saxby (obs. 11) considers:—

1st. The direction must have been S. 70° W., probably 71° 45′, being the complement of magnetic declination.

2nd. The proper motion to have been over a mile a minute.

3rd. The path was vertically over a line on the earth's surface at a least distance from Greenwich of 72 miles, with a height of 44 miles.

4th. The object must have been in the zenith over North Belgium, the Boulogne district, Cherbourg, and the north coasts of Brittany.

This was before the foreign observations were reported; and subsequently Mr. Saxby, after stating that the beam passed in the zenith at Bruxelles (M. Moutigny), and at Laon was seen to northward of the zenith gliding round the upper edge of the great main arch of the aurora, puts the actual elevation "without risk of error" as between 40 and 45 miles. Mr. Taylor (obs. 14), using the observations at York and Woodbridge, deduces a height of 212 miles; and, using those at Hungerford and York, finds 192 miles for height. He considers the beam must have passed overhead in the north of Italy and south of France, and must have been 200 miles in length. Subsequently (upon receipt of the foreign observations) he makes it 70 miles in height when over Belgium, but considers it must have been 150 miles high during the latter part of its course. As to the York observation, it seems desirable to notice that Mr. Taylor does not seem to have much confidence in his own estimate of the beam's apparent distance below the moon; and this estimate is dissented from by a relative who was watching the phenomenon at the same time. Mr. Backhouse ('Nature,' pp. 141 & 315) at first considered the height very considerable; and both he and Mr. Taylor thought Mr. Saxby's estimate of 44 miles too low, probably from near stations being used in the calculations. Later on Mr. Backhouse wrote me he thought 200 miles not an improbable height.

I may here mention that I have not heard of any observations north of York. I made inquiries at Liverpool of the

Astronomical Society recently established there, but could not hear of any; and it is much to be regretted that one from France is all we hear of from that country.

Upon the foregoing points, Prof. Alexander S. Herschel has very kindly communicated to me, and placed at my disposal, some remarks and calculations to the following effect. He considers that the supplied data (the foreign observations had not then been received) all corroborate each other very fairly, the Hewarth (York) observation excepted, which cannot, he thinks, be usefully employed.

The main body of descriptions serves to track very exactly across the south of England what may be called the shadow-line of the phenomenon thrown by the moon. This is so clearly marked out running magnetic E. and W. from Woodbridge in Suffolk, across Hungerford in Berks, into Devonshire and Cornwall, that the inclination of the beam's path to the geographical meridian (or, rather, to a parallel of latitude) can be assigned almost exactly. But this average result of the observations will of course bear a little variation according to the amount of confidence that we place, and the changes that we think fit to introduce into the interpretation of some of the descriptions. A line drawn subject to such slight variation will be inclined 24° to the geographical east and west line, which is not only a steeper pitch than the actual magnetic variation (about 20° W.) in the part of England where the shadow-path lay, but, *à fortiori*, considerably steeper yet than the real slope of magnetic variation in the region of France (about 17° or 18° W.) where the beam really moved, and was shadowed into England. A line inclined at 18° to E. and W. geographical may, however, be drawn along the central eclipse track of the observations, which will do but little violence to them, and represent them nearly, if not quite, as well as the former line. Whichever shadow-route we adopt, persons placed north (and 10° W.) of it in the direction the moon shone to, would see it *under* the moon at a distance in degrees exactly in proportion to their distance in miles (in that direction) from the shadow-track, or, if placed south of it, *over* the moon in the same way. To ascertain how many miles of displacement in station go to a degree of departure of the object's apparent sky-course above or below the moon, we have only, on the supposition that the same rate of displacement per degree belongs to each of the observations (that is, supposing that all parts of the object's course shadowed by the moon were at one and the same height above the earth, or that its course was really parallel to the earth's surface, or horizontal all the time that it was under observation), to collect all the

observers' distances from the shadow-line, and degrees of "above" or "below" view of the beam's centre relative to the moon's centre as they observed it, into two sums, and then to divide the mileage sum by the degree sum, and the result will be the best average value of the rate that the observations can afford. Exact angular centre differences are only given at Bristol, Guildown, Chatham, St. Ives, and Hewarth (York); and these agreeing very fairly (except the Hewarth one), and the distances being taken from the *first* presumptive track, the result is found to be a total of 280·5 miles for 14·1 degrees of ☽ parallax, or an average rate of 5° to 100 miles. This, projected with a protractor, would make the beam's height 215 miles over Bordeaux, but with a want of probability of such a height and distance. Abandoning therefore the Hewarth observation and accepting the other four, we get in figures as follows:—

Bristol	23 miles	=	1°·6
Guildown ...	24·5 „	=	2·0
Chatham ...	33 „	=	2·0
St. Ives.....	37 „	=	5·5
	117·5 „	=	11·1
∴	100 „	=	9·4

and this gives by projection a height of 92 miles 180 miles south of the shadow-line. Prof. Herschel at this point remarks that, as the result of his experience of the heights of the rayless milky auroral arches, obtained by good parallaxes of them, he has found they constantly occur within a few miles of 100 high, and that possibly the St. Ives observer's parallax may be a little excessive. Taking now a shadow-line inclined 18° to the geographical E. and W. direction (for the moving beam must have lain over a part of France where 18° was about the extent of magnetic variation), measuring the distances again, and preferring this time to use 5° instead of a mean of 5° and 6° as the St. Ives's parallax, we have as follows:—

Bristol	17 miles	=	1·6
Guildown ...	24 „	=	2·0
Chatham ...	27 „	=	2·0
St. Ives.....	41·5 „	=	5·0
	109·5 „	=	10·0
∴	100 „	=	9·65 = 9⅔°.

Projected with the ☽'s altitude at Guildown (28½°), these figures will give a height of 100 miles at a distance of 185 miles south of the shadow-line (see Pl. VII. fig. 1); or if, instead of using so large an angle as 9°·6 to protract with, we prefer to

Fig. 1.

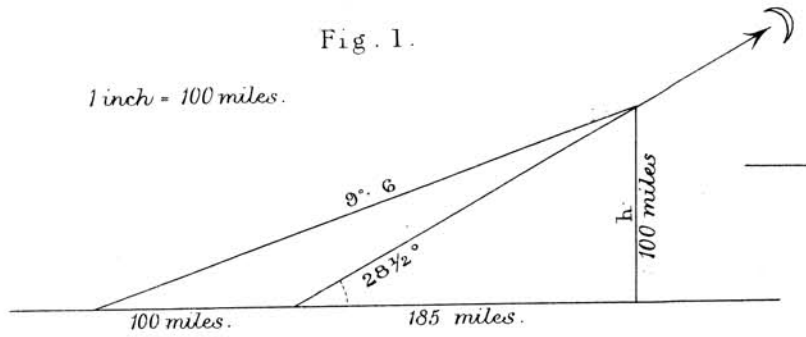
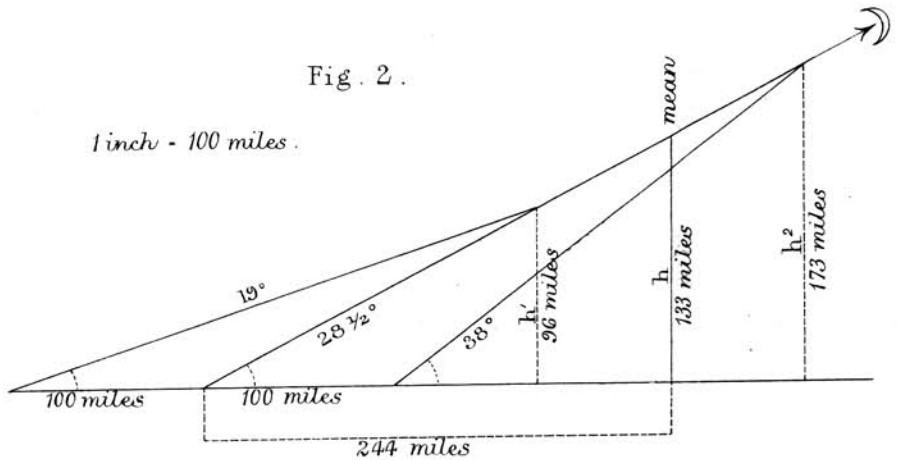


Fig. 2.



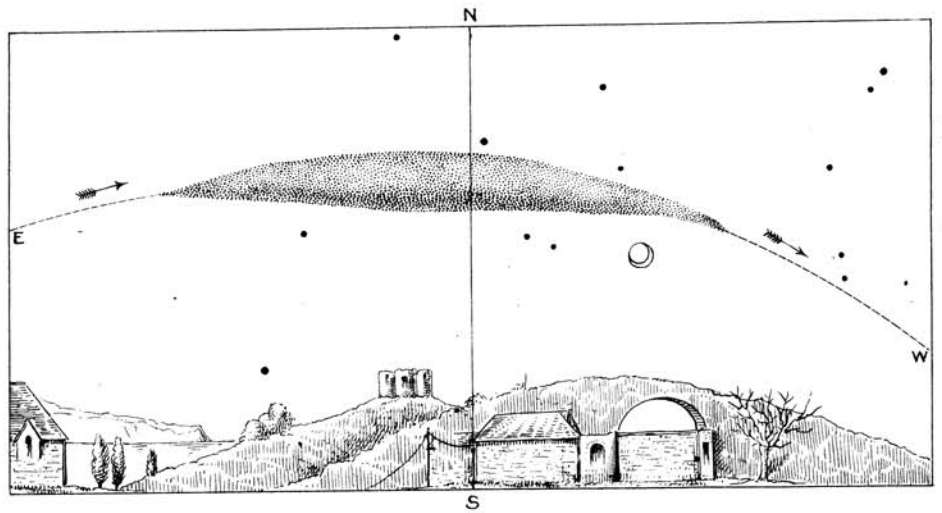


Fig. 6.

Passage of Auroral beam, 17th Novr 1882. as seen from Guildown Observatory Lat. 51°13'39"N Long 0°28'47"W.

Fig. 5.

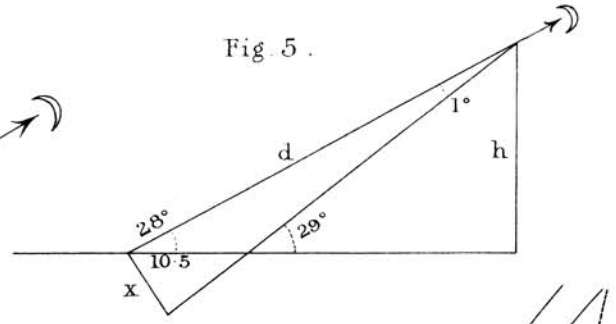


Fig. 4

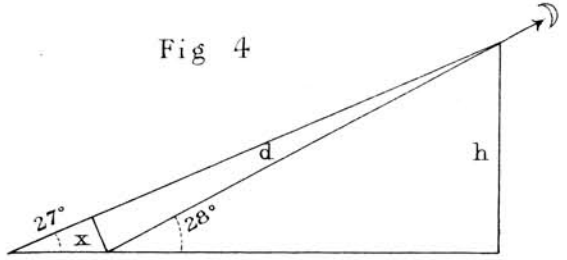
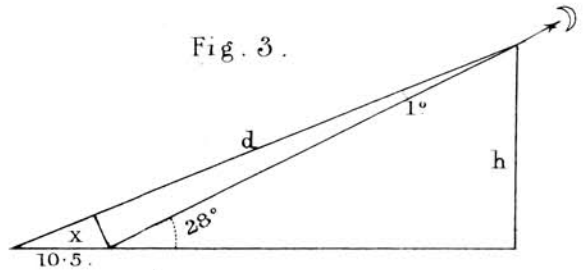


Fig. 3.



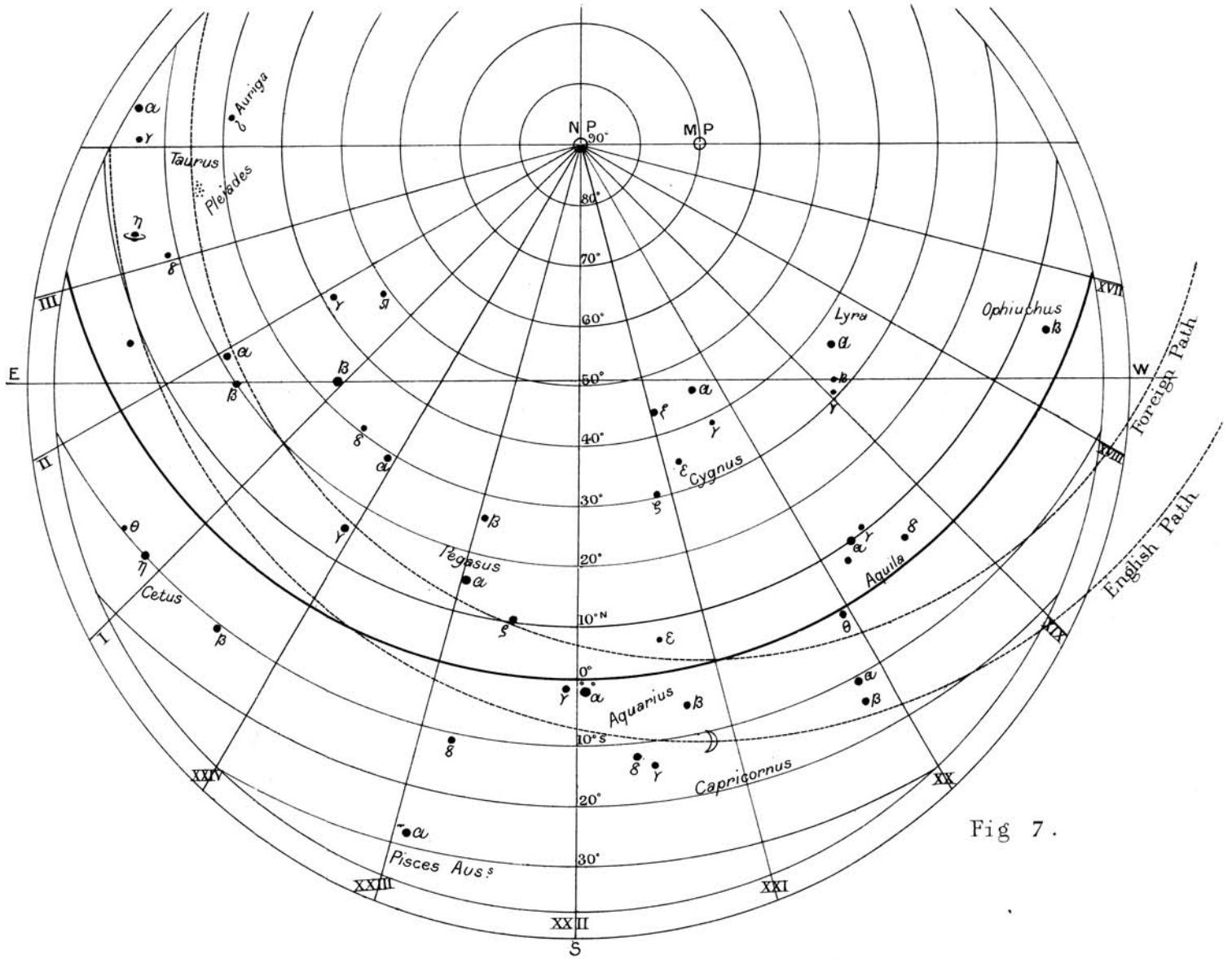


Fig 7.

Course of Auroral beam 17th Novr 1882, among the Stars.

Mintern Bros. lith.

used 100 miles station-distance on each side of the shadow-track so as to get two heights, h^1 and h^2 (see fig. 2), the mean of the two heights obtained, viz. 96 and 173 miles, will be as accurate a result as the observations can be expected to afford, and will = **133** miles.

Upon referring this last projection to Prof. Herschel, after alluding to its being after all only a rough procedure to resort to a triangulation on one side or the other of the moon's apparent altitude with a converging angle so large as 10° to fix the beam's intersection by, and after noticing that, if a 100-mile base must be used, then it were better used on the north side of the shadow-line away from the moon, he then continues:—Supposing the rate of parallax close to the shadow-line to have been $9\frac{1}{2}$° per 100 miles (*i.e.* 1° per $\left(\frac{100}{9{\cdot}5}\right)$ miles = 1° per 10·5 miles), then the best way would be to consider only a small base of 10·5 miles, say, and a small converging angle of 1° corresponding with it (fig. 3), and to calculate h trigonometrically thus:—

$$\left.\begin{array}{lll} & x = 10{\cdot}5 \times \sin 28^\circ & \\ \text{and} & x = d \times \sin 1^\circ & \\ \text{and} & h = d \times \sin 28^\circ & \end{array}\right\} \quad \therefore \frac{h}{x} = \frac{\sin 28^\circ}{\sin 1^\circ} = \frac{h}{10{\cdot}5 \times \sin 28^\circ}$$

$$\text{and } \therefore h = \frac{(\sin 28^\circ)^2}{\sin 1^\circ} \times 10{\cdot}5 \text{ miles.}$$

And then testing the above method's correctness by calculating first for 10·5 miles *north* of the shadow-line, which gives (with fig. 4)

$$\left.\begin{array}{lll} x = 10{\cdot}5 \times \sin 27^\circ & \\ x = d \times \sin 1^\circ & \\ h = d \times \sin 28^\circ & \end{array}\right\} \quad \text{or } \frac{h}{x} = \frac{\sin 28^\circ}{\sin 1^\circ} = \frac{h}{10{\cdot}5 \times \sin 27^\circ},$$

$$\therefore h = \frac{\sin 27^\circ \cdot \sin 28^\circ}{\sin 1^\circ} \times 10{\cdot}5.$$

And next (by fig. 5) with the 10·5 mile base *south* instead of north of the shadow-line, obtaining

$$\left.\begin{array}{lll} x = 10{\cdot}5 \times \sin 29^\circ & \\ x = d \times \sin 1^\circ & \\ h = d \times \sin 28^\circ & \end{array}\right\} \text{ and } \therefore h = \frac{\sin 29^\circ \cdot \sin 28^\circ}{\sin 1^\circ} \times 10{\cdot}5.$$

The mean of these two should be close to

$$h = \frac{\sin 28^\circ \times \sin 28^\circ}{\sin 1^\circ} \times 10{\cdot}5 \text{ miles, or to } h = \frac{(\sin 28)^2}{\sin 1^\circ} \times 10{\cdot}5,$$

as given in the first formula, of which the last two are the criteria to show how far such a mean differs from the use of the rule directly on each side of the shadow-line. The resulting figures are found to be:—

Formula No. 1 $h=132{\cdot}6$ miles.
„ { „ 2 $h=128{\cdot}2$ „
„ { „ 3 $h=136{\cdot}9$ „

And the mean of Nos. 2 and 3 gives us

$$h=\mathbf{132{\cdot}55} \text{ miles};$$

in curiously close accord with that obtained by actual projection (fig. 2), viz. **133** miles.

The course the beam pursued would be, at 185 miles from the shadow-line (fig. 1), passing from a little S. of Dresden to Frankfort, then between Bruxelles and Paris, but nearer the latter place and a little N. of it, across Evreux to Quimper; while at 244 miles (fig. 2) we should find it begin at Prague, then to Worms, across Fontainebleau a little S. of Paris, to Nantes. In either case the line would be slightly curved, from its getting into regions where the magnetic variation becomes gradually greater towards the west. As to the speed of motion, a path of between 800 and 900 miles long seems to have been traversed in some 80 or 90 seconds, giving a rate of 10 miles per second.

Prof. Herschel concludes by remarking that he has seen abortive bright streamers move along stationary milk-white auroral bands; and this "shuttle phenomenon" was, he thinks, a streamer-base, or "tendency to shoot up rays," travelling as a nucleus or concentration of light along an arc or bow otherwise invisible, as streamer-bases, though more faintly visible, frequently do along luminous sharp-edged phosphorescent-looking arches. It will be noticed that this last remark of Prof. Herschel's well accords with Mr. Joseph Clark's and my own observations—that the beam seemed to be following a definite and, as it were, "bespoken" track.

It may here, too, be remarked that observers who did not notice the "beam" do mention an arch or arches at about $5^{h}\ 30^{m}$, which, except for the former's flying evanescent character, must have much resembled it.

Two such observations by Mr. Clark and Mr. Clapham (obs. 22 and 23) are comprised in the particulars scheduled. Mr. Clark speaks of a "green" arch, a colour which seems to have been particularly dominant in the 17th of November aurora. Mr. Clapham describes a stationary arc formed of two conical-shaped lights, with apices meeting about the zenith. Dr. Roxburgh, in his letter to Prof. Smyth before

referred to, speaks of a number of arches parallel to the usual one being seen at Bournemouth, one across the zenith which changed in position but slowly. Other observers speak of such arches as distinguished from the usual forms of arch in the north; and the evidence generally tends to the probability that the beam itself may have been the transient lighting-up by a passing glow of an otherwise invisible arc. As regards the beam's apparent course among the stars the observations are not numerous. The Astronomer Royal (obs. 3) speaks of its passing "nearly along a parallel of declination." Mr. Dobson (obs. 5) states that it rose a little south of Aldebaran, slid along at the same N.P.D., and disappeared under Altair. Mr. Worthington (obs. 15) describes it as rising below and to the right of Saturn, but does not trace it further. Mr. Munro (obs. 9) mentions that it rose vertically below the Pleiades. Mr. Saxby (obs. 11) assigns to it a trajectory much flatter than the stars.

For foreign positions we find Prof. Oudemans (obs. 24) at Utrecht giving a precise description, viz. that it rose just above Aldebaran, passed above Saturn, went through the Pegasus quadrant, and sank south of the three Eagle stars. Prof. Zeeman at Zonnemaire (obs. 25) traced it through Aldebaran and α Pegasi. And, lastly, the Editor of *Ciel et Terre* (obs. 28) at Bruxelles says it appeared between ι Aurigæ and α Tauri, and descended between β and χ Ophiuchi. In fig. 7 I have constructed a star-map for the evening in question at Guildown; and on this are traced two dotted lines showing the home and foreign apparent tracks of the "beam." It will be seen that these are in the main conformable to the general tenor of the descriptions, and are in fact portions of circles struck from the equivalent to the magnetic pole as then situate. Circles struck from the magnetic pole on the terrestrial globe will in like manner be found fairly to correspond with Prof. Herschel's assigned paths.

In fig. 6 is found a diagram drawing (with the stars approximately fixed in their apparent places) showing the "beam" as it appeared from Guildown Observatory during the culminating portion of its passage.

Having thus traced the "beam" to be truly part of the aurora, and also having deduced as near as may be from the collected observations the duration and direction of its flight above the earth's surface and its approximate height, it remains to say something of its physical character. This question becomes interesting from the fact that several correspondents to scientific journals and papers have attributed to the phenomenon some sort of "meteoric" character, while

others have, with more precision, claimed it to be a favourable specimen of "cosmic dust" display. The best known and most zealous advocate of this "cosmic dust" theory, which not only touches the character of our "beam" but that of auroral displays in general, is Prof. Groneman, of the Ecole M. de l'Etat at Groningen (Pays-Bas).

In my 'Auroræ' (p. 64) I have briefly referred to the Professor's theory, of which I had only then seen a condensed account; but subsequently he very kindly sent me a full print of his "Théorie cosmique de l'aurore polaire" (*Estratto dall' Appendice alle Memorie della Società degli Spettroscopisti Italiani*, 1878, vol. vii.). In chapter ii. ("l'hypothèse fondamentale") of this work, the theory is expounded in connexion with Schiaparelli's discovery of "poudre cosmique" circulating round the central star of our system in elliptic rings, meeting the earth in its orbit, occasioning shooting-stars, meteors, &c., and, amongst other phenomena, luminous apparitions such as auroræ.

This paper is worthy of attentive reading and consideration; for while in its twenty chapters main stress is laid upon the general connexion of the "cosmic dust" with auroræ, with the zodiacal light, and with the "Gegenschein" or antisolar light, the particular phenomena of auroræ are fully and elaborately discussed in detail.

Prof. Groneman has followed up this paper by letters in 'Nature,' vol. xxiii. p. 195, and vol. xxvii. p. 388, and by an article in the same volume, p. 296. The article last referred to is particularly valuable, not only as supplying us with the observations at Utrecht and at Zonnemaire before cited, but as giving a drawing of an auroral arch seen at Groningen, Nov. 2, 1871, resembling the beam, as well as some accounts of other similar phenomena seen during auroræ, and some statistics as to the heights of auroræ, including those of Heis and Flögel, 10 to 100 geographical miles (46 to 461 English miles), Tromholt, 17 geogr. miles, Galle, 40 to 60 geogr. miles, and Prof. Groneman himself, 59 geogr. miles. He considers the course of the beam to have been a great circle cutting the horizon and also the equator in two opposite points. On the cosmic theory we may at once remark that in some respects it is quite possible that auroræ and clouds of meteorites circulating within our atmosphere may resemble one another; but I confess I am not prepared to declare in favour of the "théorie cosmique" as a satisfactory explanation of auroral phenomena. One adverse point urged by Mr. Backhouse ('Nature,' p. 315) is the fact that meteors are mostly given to fly in all directions, while auroral arches and beams (of which this one

is an example) describe courses along parallels of magnetic latitude; and hence he does not consider its course to have been a meteor-one.

Another divergent point is the rate of motion. The "beam" had, as the result of the observations I have recorded and in Prof. Herschel's opinion, a rate of some 10 miles per second; while in Guillemin's *Le Ciel*, p. 235, we find the information that the rate of flight of bolides is considered to be 70 to 175 kilometres (40 to 130 English miles) per second.

A third, and to my mind the strongest, objection to the Professor's theory is the well-known spectrum of the aurora. This spectrum is unique of its kind, and has been long since dissociated from that of the zodiacal light (which light Prof. Groneman connects with auroræ and with the cosmic theory), Prof. Piazzi Smyth and Pingle having incontestably proved the latter to be a continuous one without any bright lines whatever. Nor does the auroral spectrum at all resemble that of meteors or bolides. The last, according to Konkoly, consists of rays (bright lines) of iron and other metals (probably nickel, cobalt, and manganese, J.R.C.). The aurora-spectrum does not give the idea of a metallic spectrum (with a possible exception of the red and citron lines), but rather that of a gaseous character; and certainly a positive coincidence of the red and citron lines with any known metal line is far from being proved. Prof. Groneman has indeed quoted me in his *Théorie Cosmique* (p. 13) as, in Phil. Mag. ser. 4, vol. xlix. p. 249 (should be 265), remarking on an "exact concordance" between the iron and aurora spectra. But this is certainly going further than I intended; for my expression, "*close* coincidences," is too strongly rendered by "concordance *exacte*." If, too, the plate of spectra accompanying that paper be examined, the state of the matter in fact stands thus as to coincidences, thus:—

W.L.	Aurora lines.	W.L.	Iron lines.
6297,	the red line	Not compared.	
5569,	the citron line.....	5571,	one of three close [together.
5390,	in blue	5370	
5233,	do.	5231	
5189,	do.	5192	
5004,	do.	.....	no comparable lines.
4694, 4629,	do.	a band	no comparable lines.

I have also very considerably qualified any such remark as that above alluded to by pointing out ('Auroræ,' pp. 118–170) that the connexion between the two spectra, though it might be suspected, cannot be considered as proved, the fine iron lines

being so numerous that a coincidence of some of these with the coarser aurora lines may after all be purely accidental. (In 'Photographed Spectra' I have given the spectrum of a meteorite when burnt in the electric arc, which presents several hundred lines in the portion of the spectrum lying between F and H alone.)

In regard to Prof. Groneman's height of auroræ as compared with Prof. Herschel's deductions, it may be desirable to mention two recent authorities on the subject as giving heights very close upon those assigned by Prof. Herschel: viz. Herr Sophus Tromholt, in an article on Auroræ ('Nature,' vol. xxvii. p. 295), speaks of an opinion he has formed as to the height of the aurora, viz. 150 kilometres (90 miles); Baron Nordenskjöld ('Nature,' vol. xxv. pp. 319-321), in the "Scientific Work of the Vega Expedition," Part I. pp. 401–452, speaks of our globe as being adorned with an auroral crown whose inner edge was usually, during the winter of 1878–79, at a height of about 0·03 radius of the earth above its surface (that is, about 115 miles).

While on this part of the subject, it may be useful to refer to the vacuum experiments of Drs. De La Rue and Müller, detailed by them in a paper on the height of the Aurora Borealis read before the Royal Society ('Nature,' vol. xxii. p. 33). Appended to this is a table of deductions from actual observations, showing, amongst other particulars, a scale of miles of auroral heights, and remarks on the character of the electric glow at such heights. 11·58 miles gave a full red glow, 27·42 a carmine, 32·87 a salmon-coloured, 37·67 maximum brilliancy, 81·47 pale and faint, and at 124·15 miles "no discharge could occur." A note appended to the table states "it is conceivable that the aurora may occur at times at an altitude of a few thousand feet"*.

The experiments, however, are open to the remark that the discharge was taken in hydrogen gas and not in air, and that there was an absence of any observation of aurora-like lines or spectrum in connexion with the discharge. Otherwise the experiments would go to show that the auroral discharge generally takes place at a lower level than most observers have ascribed to it, and, if they could be depended on as fulfilling all the conditions of the aurora, would place the beam at a height of 133 miles within the region where no discharge could take place. Possibly, however, the medium in which the discharge was taken might affect the results obtained to the extent of this discrepancy.

* Dr. De La Rue acquaints me he has further experiments in progress.—J. R. C.

Two other recent matters in connexion with the aurora-spectrum seem to claim an attention before concluding this paper. The first is communicated to 'Knowledge' by Mr. Cory, of Buckhurst Hill (before mentioned). In a letter to that journal (vol. iii. no. 62), dated 30th of November last, after describing the spectrum of the beam, he says :—"Upon a previous occasion, when observing the aurora of October 2, I noticed a bright line in a similar position, and for a few minutes only *three distinct bright lines in the red end of the spectrum*" [the italics are mine]. In a letter to me subsequently, Mr. Cory states he is sure of the lines (in a Browning miniature spectroscope), though he could not give their exact positions—facts which he repeated in a personal interview, adding that by the red end of the spectrum he meant the region on the less-refrangible side of the D lines. Prof. Stokes, in the 'Arctic Manual,' 1875 (p. 26), says "and there are also one or more lines in the red in red auroras." I am not aware of the authorities upon which this statement is made. Although varying W.L. positions have been assigned by different observers to the red line, I have hitherto assumed them to refer to the same line, and did not think more than one had been seen.

With Mr. Cory's uncertainty of positions, it is not easy to make much of his observation; but a circumstance to be noted in connexion with it is, that the single red line generally remarked falls within a group of nitrogen lines, and it would be interesting if the additional lines were found to do so too.

The other matter to be referred to is the recent procuring of an "Artificial Aurora" (as it has been not very happily called) by Prof. Lemström, a name long known in auroral researches.

At present our information on the subject is somewhat meagre. In 'Nature' (vol. xxvii. p. 322) we find that a telegram, dated December 11th last, had been received by the Finnish Academy of Science from Professor Lemström, as chief of the Finnish Meteorological Observatory at Sodankylä. This stated that, having placed a battery with conductors covering an area of 900 square metres on the hill of Orantunturi, he found the cone to be generally surrounded by a halo yellow-white in colour, which faintly but perfectly yielded the spectrum of the aurora. This he considered formed a direct proof of the electrical action of the aurora, and opened a new field in the study of the physical condition of the earth.

A further telegram stated that experiments with the aurora, made December 29th in Enare near Kakala on the hill of Pictarintunturi, confirmed the results of those at Orantunturi. On that date a straight beam of aurora was seen over the galvanic apparatus. It was also stated that, from the magnetic observa-

tions, the terrestrial current ceases below the aurora arc; while the atmospheric current rapidly increases, but depends on the area of the galvanic apparatus, to which it seems proportional.

In a letter to 'Nature' (same volume, p. 389) Prof. Lemström explains that the apparatus was constructed of uncovered copper wire provided at each half metre with fine erected points. The wire was led in slings to the top of the hill, and reposed on the usual telegraph insulators. From one end of this wire was conducted a covered copper wire on insulators to the foot of the hill 600 feet high, which there joined a plate of zinc interred in the earth, and in the circuit was put a galvanometer (no battery is mentioned, J. R. C.). This apparatus produced the halo at Orantunturi and the straight beam at Pictarintunturi as the positive current in the galvanometer at both places. The terrestrial current diminishes (or ceases) below the belt of maxima of the aurora.

In the 'Daily Telegraph' newspaper of March 1st, 1883, Prof. Foerster is stated to have given an account of these experiments, and to have added that the astounding result was the formation of an aurora borealis rising above the mountain-top to an elevation estimated at 300 feet. In a subsequent number of the same paper (March 5th), under a heading "Artificial Aurora," an article is found which alludes in detail to several points in connexion with the phenomena involved, but which to my mind are those really requiring further explanation. One of these is the direct comparison of the electric glow in an exhausted receiver with the auroral discharge. It may be conceded that the two *look* alike; but it is well known that here the comparison ceases, as every effort has been made for years past, without success, to obtain the aurora-spectrum from such a source. Next, the phenomena are attributed to atmospheric electricity; but in point of fact it is strong manifestations of earth-currents, and not of atmospheric electricity, which have generally accompanied auroral displays, notably that of November 17th last. Again, while Prof. Lemström's actual aurora and Planté's artificial auroræ are alluded to in the article in question as connected with the *positive* pole, it was in the glow of the *negative*, or violet pole, that the late Prof. Ångström sought for, and considered he had obtained, an aurora-spectrum.

With regard to the spectrum obtained by Prof. Lemström, if the instrumental resources were adequate for exact measurement, the observation obtained from such a source is doubtless reliable; but it should, by way of precaution, be remembered that even scientists of such calibre as Ångström and Respighi

were on occasions deceived by the presence of a concealed aurora, and thus the zodiacal light and the aurora spectra were at first confounded. Seeing, also, how up to the present time we have quite failed to produce in our laboratories any form of electric discharge which by its spectrum can fairly be pronounced as of an auroral character, it would seem desirable to wait the result of later and fuller particulars from the learned Professor before passing a definite judgment on the matter. We do not at present hear of any comparisons of the "artificial" aurora-spectrum with other spectra which will explain its true and so long hidden character; though doubtless, if we can succeed in establishing an aurora "en permanence," good results may reasonably be expected to follow, one principal cause of failure in explanation of the Aurora mystery being the infrequency of the opportunities afforded of examining its spectrum and comparing it directly with others.

Guildown, April 6, 1883.

XLVIII. *A new Form of Constant-Temperature Bath.* By W. W. J. Nicol, *M.A., B.Sc., F.R.S.E., Lecturer on Chemistry, Mason College, Birmingham* *.

THE want of a simple and, at the same time, reliable constant-temperature bath has been felt by all who have made specific-gravity determinations. The following apparatus, which has been found thoroughly efficient, was devised by me during the course of my experiments on the specific gravity of salt-solutions, the results of which have been recently published †.

The apparatus consists of three parts—the bath, the heating arrangement, and the thermostat. The bath is of copper, measuring 200 millim. in length, 200 millim. in depth, and 90 millim. in width—a size I found most convenient for use with the Sprengel tubes described in the 'Chemical News' (February 1883). Near one end is soldered a wide brass tube (C, fig. 1) with a slot down one side: this is intended to receive the thermostat and thermometer. The water in the bath is agitated by means of a current of air supplied by a Fletcher's blower. The air escapes from a perforated tube lying on the bottom of the bath.

* Communicated by the Author.

† Proceedings Roy. Soc. Edin. 1881–82; *Ber. deut. Chem. Ges.* 1882, p. 1931; Phil. Mag. 1883, February; Chem. Soc. Journ. 1883, March.