friend of Luther and as one of the editors of his works, was born in 1519 in the county of Mansfeldt, or, more probably, in the town of Weimar. After completing his education at the university of Wittenberg, where he heard the lectures of Luther, he became tutor to Count Mansfeldt, and in the war of 1544–5 accompanied the army as field-preacher. For some months afterwards he resided with Luther as his *famulus* or private secretary, and was present at his death in 1546. In the following year he spent six months in prison along with John Frederick, elector of Saxony, who had been captured by the emperor, Charles V. He held for some years the office of court-preacher at Weimar, but, owing to theological disputes, was compelled to resign this office in 1561. In 1566 he was appointed to the Lutheran church at Erfurt, which post he held, though not without serious differences with his fellow-clergymen, till his death in 1575. Besides taking a share in the first collected or Jena edition of Luther's works, Aurifaber sought out and published at Eisleben in 1564–5 several writings not included in that edition. He also published Luther's *Letters* (1556, 1565), and *Table Talk* (1566).

AURIFABER, JOANNES, a Lutheran divine, born at Breslau in 1517. He was educated at Wittenberg, and was there specially attracted to Melanchthon, with whom he ever afterwards remained on terms of close friendship. After graduating in 1538 he spent twelve years as *docent* at the university, and having then received his doctorate of divinity, was appointed professor of divinity and pastor of the church of St Nicholas at Rostock. He distinguished himself by his prudence and conciliatory disposition, took a leading part in the composition of the regulations for the Mecklenburg Church, and was successful in allaying some religious disputes in the town of Lübeck. The Grand-duke Albert of Prussia, who was very desirous of healing the differences in the Prussian Church caused by the discussion of Osiander's doctrines, was attracted by Aurifaber, invited him to Königsberg in 1553, and in the following year appointed him to the professorship of divinity in that university, and to the presidency of the Samland diocese. Aurifaber, however, found it impossible to conciliate all parties, and in 1565 returned to Breslau, where, for the three remaining years of his life, he discharged the joint offices of pastor in the church of St Elizabeth and director of the Lutheran Church and schools. He died 19th October 1568.

AURILLAC, the capital of the department of Cantal, France, situated on the right bank of the Jourdanne, which is here crossed by a handsome bridge. It contains tribunals of primary instance and commerce, a communal college, societies of agriculture, arts, and commerce, a public library, and a museum. Most of the town is of comparatively modern construction, its more ancient buildings having suffered severely in the religious wars of the 16th century. Of highest claims to antiquity are portions of the castle of St Etienne, the church of St Géraud, and a Benedictine abbey, which is regarded by many as the original nucleus round which Aurillac gathered. There is a statue of Sylvester II., who was a native of the town, and was educated in the abbey, which soon afterwards became one of the most famous schools of France. The manufactures consist of tapestry, lace, cutlery, paper, leather, &c., and a considerable number of horses are bred. Population in 1872, 11,098.

AURORA, the Roman personification of the dawn of day, corresponding to the Greek goddess Eos (*q.v.*).

AURORA POLARIS

AURORA POLARIS, AURORA BOREALIS and AUSTRALIS, POLAR LIGHT, NORTHERN LIGHTS, or STREAMERS, an electrical meteor, appearing most frequently in high latitudes, in the form of luminous clouds, arches, and rays, of which the latter sometimes meet at a point near the zenith, and form what is called a *boreal crown*. The arches are sometimes single; sometimes several concentric ones are seen, and they are usually nearly stationary, or move slowly southward. They cross the magnetic meridian at right angles, and, therefore, in England, have their centres nearly N.N.W. The rays rise perpendicularly from the arches, but are sometimes seen detached, or when the arch is below the horizon. They are parallel to the dipping needle, or, in other words, to the curves of magnetic force; and the boreal crown, at which they appear to meet, is merely an effect of perspective. This point is in England about 70° in altitude, and nearly S.S.E. of the zenith. The rays are seldom stationary, but appear and disappear suddenly, shooting with great velocity up to the zenith, and moving slowly eastward or westward, but most commonly the latter. They sometimes cover the whole sky, and frequently have a strong tremulous motion from end to end. This tremulous motion is sometimes seen also in the arches when near the zenith; and Benjamin V. Marsh mentions a case in which the matter of the arch had the appearance of a rapid torrent flowing from east to west. A rare form of aurora is that in which the rays appear to hang from the sky like fringes or the folds of a mantle. The ordinary colour of the aurora is a pale greenish-yellow, but crimson, violet, and steel-colour are not uncommon. Crimson auroras have often been imagined by the superstitious to be omens of war, pestilence, and famine; and lively imaginations have seen in their motions—

> "Fierce fiery warriors fight upon the clouds
> In ranks, and squadrons, and right form of war."

They were called by the ancients *chasmata*, *bolides*, and *trabes*, according to their forms and colours. In Shetland, where they are very frequent, and in the north of Scotland, they are known as the "*merry dancers*" (perhaps the ancient *caprœ saltantes*); while, from a curious passage in Sirr's *Ceylon and the Cingalese*, vol. ii. p. 117, it seems that the aurora, or something like it, is occasionally visible in Ceylon, and that the natives call it the *Buddha lights*. Mr Jansen says, however, that the great aurora of 4th February 1872, which was seen at Bombay, was not visible in Ceylon. In many parts of Ireland a scarlet aurora is supposed to be a shower of blood, and under this name is not unfrequently mentioned in the old annals, always in connection with some battle or the murder of a great chief. The earliest mentioned was in 688, in the *Annals of Cloon-mac-noise*, after a battle between Leinster and Munster, in which Foylcher O'Moyloyer was slain. It was observed at Edessa in 502, and in Syria in 1097, 1098, and 1117.

The only thing resembling a distinct history of this phenomenon is that which has been given by Dr Halley, in the *Philosophical Transactions*, No. 347. The first account he gives, taken from a book entitled *A Description of Meteors*, by W. F., D.D., reprinted at London in 1654, describes the appearance of what is called by him *burning spears*, which were seen at London on the 30th January 1560. The next appearance, according to the testimony of Stow, was on the 7th October 1564. In 1574 also, according to Camden and Stow, an aurora borealis was observed two nights successively, viz., on the 14th and 15th of November, having much the same appearances as that described by Dr Halley in 1716. Again, an aurora

was twice seen in Brabant, in the year 1575, viz., on the 13th of February and 28th of September. Both appearances were described by Cornelius Gemm, professor of medicine at Louvain, who compares them to spears, fortified cities, and armies fighting in the air. Michael Mæstlin, tutor to Kepler, states that at Backnang in Würtemberg these phenomena, which he styles *chasmata*, were seen by himself no less than seven times in 1580. In 1581 they again appeared in great splendour in April and September, and in a less degree in some other months of the same year. In September 1621, a similar phenomenon was observed all over France, and described by Gassendi, who gave it the name of *aurora borealis*; yet neither this, nor any similar appearance posterior to 1574, is described by English writers till the year 1707. From 1621 to 1707, indeed, there is no mention made of an aurora borealis having been seen at all; and, considering the number of astronomers who during that period were continually scanning the heavens, it might almost be supposed that nothing of the kind really made its appearance until after an interval of eighty-six years. A small one was seen in November 1707; and during that and the following year the same appearances were repeated five times. The next on record is that mentioned by Dr Halley in March 1716, which from its brilliancy attracted universal attention, and was considered by the common people as marking the introduction of a foreign race of princes. Since that time these meteors have been much more frequent, and most of our readers must have seen the brilliant displays within the last few years which have been visible over the whole of Europe.

One singular phenomenon which seems to be connected with the aurora is that of a dark bank of cloud below the arches, and usually just above the northern horizon. Although this appears decidedly darker than the uncovered portion of the sky, it is of so thin a character that stars can be seen through it, as well as through the auroral arches and rays, with but little diminution of brightness. It is, however, quite possible that this cloud is only the somewhat misty open sky near the horizon, which appears darker by contrast with the bright arch above it.

It has been repeatedly affirmed that cracking, hissing, or whizzing sounds have been heard proceeding from the polar lights, and the natives of high latitudes are almost unanimous in alleging that this is sometimes the case. Scoresby, Richardson, Franklin, Parry, Hood, and later observers seem to have listened in vain for such noises, and it seems that in the intense cold of the Arctic night the contraction of the ice, or its cleavage under the pressure of approaching tempests, produces sounds exactly such as are described. Still, mere negative evidence must be received with caution, and it is very possible that in high latitudes such sounds may occasionally be heard, since the electric discharge seems to originate near the poles. The aurora, too, seems to vary greatly in height, and in lower latitudes is usually at such an altitude that audible sounds from it are quite impossible. Musschenbroeck says that the Greenland fishers in his time assured him that they had frequently heard noises proceeding from the aurora borealis, and his testimony is confirmed by that of many others. There is no *a priori* improbability of such sounds being occasionally heard, since a somewhat similar phenomenon accompanies the brush discharge of the electric machine, to which the aurora bears considerable resemblance.

Numerous observers (*Nature*, iv. 27, 47) have attested the occasional visibility of aurora by daylight. In the *Transactions of the Royal Irish Academy*, 1788, Dr H. Ussher notices that aurora makes the stars "flutter" very much in the telescope, and states that, having noticed this effect strongly one day at 11 A.M., he examined the sky, and saw an auroral corona with rays to the horizon. J. Glaisher, Franklin, and others, have also observed the phenomenon. It is scarcely possible that a light so faint as not even to obscure the stars should be visible in sunlight, and such facts would seem to suggest that the auroral light is developed in cloud or mist of some sort, which may become visible by reflected light, as well as by its own. Franklin says, "Upon one occasion the aurora was seen immediately after sunset, while bright daylight was still remaining. A circumstance to which I attach some importance must not be omitted. Clouds have sometimes been observed during the day to assume the forms of aurora, and I am inclined to connect with these clouds the deviation of the needle, which was occasionally remarked at such times." The writer has seen aurora which could not be distinguished from clouds, till the further development of the display made their real nature evident. Dr Richardson thinks he has observed a polarity in the masses of cloud belonging to a certain kind of cirro-stratus approaching to cirrus, by which their long diameters, having all the same direction, were made to cross the magnetic meridian nearly at right angles. But the apparent convergence of such masses of cloud towards the opposite points of the horizon, which have been so frequently noticed by meteorologists, is an optical deception, produced when they are situated in a plane parallel to that on which the observer stands. These circumstances, says Dr Richardson, are here noticed, because if it shall hereafter be proved that the aurora depends upon the existence of certain clouds, its apparent polarity may, perhaps, with more propriety, be ascribed to the clouds themselves which emit the light; or, in other words, the clouds may assume their peculiar arrangement through the operation of one cause (magnetism, for example), while the emission of light may be produced by another, namely, a change in their internal constitution, perhaps connected with a motion of the electrical fluid. D. Low (*Nat.*, iv. 121) states that he has witnessed as complete a display of auroral motions in the cirrus cloud as he ever beheld in a midnight sky. He thinks that all clouds are subject to magnetic or diamagnetic polarisation, and states that when the lines converge towards the magnetic pole, fine weather follows; when they are at right angles to this position, wet and stormy. The aurora appears in these latitudes usually to occur at a height much greater than that of ordinary clouds. Dr Richardson's observations (Franklin and Richardson's *Journey to the Shores of the Polar Sea*) seem to show, however, that, in the Arctic regions, the aurora is occasionally seated in a region of the atmosphere below a kind of cloud which is known to possess no great altitude, namely, that modification of cirro-stratus which, descending low in the atmosphere, produces a hazy sheet of cloud over head, or a fogbank in the horizon. Indeed, Dr Richardson is inclined to infer that the aurora borealis is constantly accompanied by, or immediately precedes, the formation of one or other of the forms of cirro-stratus. On the 13th of November and 18th December 1826, at Fort Enterprise, its connection with a cloud intermediate between cirrus and cirro-stratus is mentioned; but the most vivid coruscations of the aurora were observed when there were only a few thin attenuated shoots of cirro-stratus floating in the air, or when that cloud was so rare that its existence was only known by the production of a halo round the moon. The natives of the Arctic regions of North America pretend to foretell wind by the rapidity of the motions of the aurora; and they say that when it spreads over the sky in a uniform sheet of light, it is followed by fine weather, and that the changes thus indicated are more or less speedy, according as the appearance of the meteor is early or late in the evening,—an opinion not improbable, when it is recollected

that certain kinds of cirro-stratus are also regarded by meteorologists as sure indications of rain and wind. Dr Richardson frequently observed the lower surface of nebulous masses illuminated by polar lights,—a fact illustrative of the comparatively low situation of these auroræ. Biot, also, in the island of Unst, observed many auroræ that could not be higher than the region of clouds. Sir John Franklin in like manner observed low auroræ. "The important fact," says he, "of the existence of the aurora at a less elevation than that of dense clouds was evinced on two or three occasions this night (13th February 1821, at Fort Enterprise), and particularly at 11 hours 50 min., when a brilliant mass of light, variegated with the prismatic colours, passed between a uniform steady dense cloud and the earth, and in its progress completely concealed that portion of the cloud which the stream of light covered, until the coruscation had passed over it, when the cloud appeared as before." Captain Parry, as stated in his third voyage, observed auroræ near to the earth's surface. It is said that while Lieutenants Scherer and Ross and Captain Parry were admiring the extreme beauty of a polar light, they all simultaneously uttered an exclamation of surprise at seeing a bright ray of the aurora shoot suddenly downward from the general mass of light, and between them and the land, which was only 3000 yards distant. The ray or beam of the polar light thus passed within a distance of 3000 yards, or less than 2 miles, of them. Further, Mr Farquharson observed in Aberdeenshire an aurora borealis not more than 4000 feet above the level of the sea. Fitzroy believed that aurora in northern latitudes indicates and accompanies stormy weather at a distance, and that straining and cracking of the ice may cause the hissing and whizzing sounds.

M. Silbermann (*Comptes Rendus*, lxviii. p. 1051) notes facts which strongly confirm the connection of aurora with some form of cirrus cloud. He says (of the aurora of 15th April 1869),—"At 11 hours 16 min. the phenomenon disappeared in a singular fashion. It appeared as if the columns of the aurora were still visible, but the stars were hidden, and it soon became obvious that fan-like cirrus clouds, with their point of divergence in the north, had taken the place of the aurora. Between 1 and 2 in the morning these clouds had passed the zenith, and let fall a very fine rain. On stretching out the back of the hand one felt a pricking of cold, and now and then there were minute scintillations in the nearest strata of air, like a hail of tiny crystals of ice, which afterwards turned to a rain of larger and larger drops. At 4 o'clock in the morning the cirrus of the false aurora was still visible, but deformed towards the top, and presenting a flaky aspect. One interesting point is, that the cirrus never appeared to replace the aurora either from the right or the left, but to substitute itself for it, like the slow changes of a dioramic view." "I had previously observed a fall of small ice crystals on the 30th April 1865. At 6 P.M. Paris seemed enveloped in a cirrus of vertical fibres, recalling those of amianthus, and more or less wavy. It was a rain of little sparkling prisms. At the same time I heard a rustling or crepitation, and on extending my hand I felt a pricking sensation of cold, and distinguished the crystals which fell and melted immediately."

In a later memoir (*Ibid.*, p. 1120) he remarks that many storm-clouds throw out tufts of cirri from their tops, which extend over a great portion of the sky, and resolve themselves into a very fine and cold drizzle, which frequently degenerates into a warmer and more abundant rain. Usually the fibres are more or less sinuous, but in much rarer cases they become perfectly rectilinear, and surround the cloud like a glory, and occasionally shine with a sort of phosphorescence. As an illustration he quotes his observations on the night of the 6th September 1865:—"A stormy cloud was observed about 11 P.M. in the N.N.W., and lightning was distinctly visible in the dark cumulous mass. Around this mass extended *glories* of a phosphorescent whiteness, which melted away into the darkness of the starry sky. Round the cloud was a single and uninterrupted corona, and outside this, two fainter coronæ broken by rifts which corresponded with each other. After the cloud had sunk below the horizon the *glories* were still visible. The light could not have been due to the moon or any foreign cause. The rays showed great mobility, and a sort of vibration intermediate between that of the aurora and the 'brush discharge' of the electric machine." He goes on to say that—

"Luminous clouds have been frequently observed. There are many examples in Gilbert's *Annals*, and we may recall also the observations of Becaria, Deluc, the Abbé Rozier, Nicholson, and Colla. Mists also are occasionally luminous, as, for instance, that observed by Dr Verdeil at Lausanne in 1753, and by Dr Robinson in Ireland."

A still more curious fact is mentioned by Sabine, who, during his magnetic survey, anchored some days at Loch Scavaig in Skye. This loch is surrounded by high and bare mountains, one of which was nearly always enveloped in a cloud, resulting from the vapours which almost constant west winds brought from the Atlantic. This cloud at nights was permanently self-luminous, and Sabine frequently saw rays similar to those of the aurora. He entirely repudiates the idea that the rays could be due to auroræ beyond the mountain, and is sure that these phenomena, whatever their nature were produced in the cloud itself.

Silbermann asserts that auroræ are preceded by the same general phenomena as thunderstorms, and concludes that everything had happened as if the auroræ of 1859 and 1869 had been storm-clouds, which, instead of bursting in thunder, had been drawn into the upper parts of the atmosphere, and their vapour being crystallised in tiny prisms by the intense cold, the electricity had become luminous in flowing over these icy particles. This view is very strongly supported by the observation of Professor Piazzi Smyth that the monthly frequency of aurora varies inversely with that of thunderstorms. The following are his numbers of relative frequency, the means of all observations of the Scottish Meteorological Society prior to 1871:—

	Lightning.	Aurora
January	24·0	29·7
February	14·4	42·5
March	7·0	35·0
April	15·4	27·5
May	37·4	4·8
June	48·0	0·0
July	53·2	0·5
August	38·4	12·6
September	22·4	36·6
October	20·8	49·4
November	15·0	32·4
December	15·0	28·8
Mean of whole year	24·0	20·1

It must, however, be remembered that the observed frequency of auroræ is much affected in Scotland by the continuous twilight during the summer months. If there be this connection between thunder-clouds and auroræ, it is not improbable that the "dark segment" is sometimes a real cloud or mist, situated at a height where the density of the air is too great for luminous discharge; and in several cases Silbermann has seen auroral rays rise from small clouds, which gradually melted entirely away, or left a small non-luminous nucleus when their electricity was discharged.

If, as would certainly be the case in a mist, any portion of the auroral light is reflected, whether it be its own or derived from some other body, it should be polarised; but so far polariscope observations are deficient, and give no certain information. It is difficult to separate the proper polarisation of the aurora from the mere atmospheric polarisation of the sky. Mr Ranyard, who appears to have used a double-imaged prism and Savart during the great aurora of Feb. 4, 1872, and also to have made some observations on that of Nov. 11, 1871, did not detect polarisation. On the other hand, Prof. Stephen Alexander, in his report on his expedition to Labrador (App. 21, *U. S. Coast Survey Rep.*, 1860), found strong polarisation with a Savart, and, singularly enough, thought it strongest in the dark parts of the aurora. The observations were made in lat. about 60°, in the beginning of July, and near midnight, but he does not state whether there was twilight or any trace of air polarisation at the time, nor does he give the plane of polarisation.

With regard to the height of auroræ, Sir W. R. Grove (*Nature*, vol. iii. p. 28) states that he saw an aurora some years ago at Chester in which the rays came between him and the houses; and Mr Ladd observed a similar case in which the lighthouse at Margate was visible through a ray. The evidence, however, appears strong that aurora is usually at a very great height. Dalton calculated the height of an auroral arch, which was seen as far north as Edinburgh, and as far south as Doncaster, and at most intermediate places, from its apparent altitude, as measured by its position in relation to the stars as seen from Kendal and Warrington, 83 miles apart. The resulting height was about 100 miles, and the position slightly south of Kendal. An observation at Jedburgh confirmed this, but some taken at Edinburgh placed it above Carlisle at a height of 150 miles. Dalton, however, considered the former reckoning the more trustworthy. Backhouse has made many calculations, and considers that the average height of auroræ ranges from 50 to 100 miles, and numerous other observers have calculated similar heights. All these observations, however, are liable to the objection, that different observers may really have seen different arches, of which, as has been remarked, there are often several concentric ones. It is not likely that this was really the case in most instances, but it has, no doubt, sometimes occurred, and may account for the heights of 500 to 1000 miles calculated by early observers. This difficulty is met by a method proposed by Prof. H. A. Newton (*Sill. Jour. of Sc.*, 2d ser. vol. xxxix. p. 286) for calculating the height by one observation of altitude and amplitude of an arch. It seems almost certain that the auroral arches are arcs of circles, of which the centre is the magnetic axis of the earth; or, at least, that they are nearly parallel to the earth's surface, and probably also to the narrow belt or ring surrounding the magnetic and astronomical poles, and passing through Faroe, the North Cape, and the north of Nova Zembla, which Loomis and Fritz have found to be the region of most frequent aurora. This being assumed, Prof. Newton finds that, d being the distance from the observer to the centre of curvature of the nearest part of this belt (which for England is situated about 75° N. lat., 50° W. long.), h the apparent altitude of the arch, 2α its amplitude on the horizon, x its height, R the earth's radius, and c the distance of the observer from the ends of the arch,—

$$\sin.\ \phi = \sin.\ d.\ \cos.\ \alpha\ \text{cosec.}\ (d+h) \quad . \quad (1),$$

$$\tan.\ c = 2\ \sin.\ h\ \sin.\ \phi\ \sec.^2\phi \quad . \quad (2),$$

and

$$x = \mathrm{R}\ (\sec.\ c - 1) \quad . \quad . \quad . \quad . \quad (3).$$

He gives the heights of twenty-eight auroræ calculated by this method, ranging from 33 to 281 miles, with a mean of 130 miles. The method, of course, rests on the assumption that auroral arches are arcs of circles, but it is decidedly confirmatory both of this assumption and of the heights calculated by other methods. It cannot well be objected that such altitudes are beyond the limits of our atmosphere, since Prof. A. S. Herschel (*Nature*, vol. iv. 504) gives the height of twenty meteors varying from 40 to 118 miles, with an average of about 70 miles, and it is almost certain that these bodies are rendered incandescent by atmospheric friction. Assuming 0° C. as the temperature at the earth's surface, and the absolute zero, −273° C., as a minimum for the auroral region, the pressure would be about 0·2 millimetre (0·0078 inch) at a height of 100 kilometres (62 miles) above the earth's surface. This result, of course, assumes a good deal; but if correct, it implies a vacuum attainable with difficulty even with the Sprengel pump. The pressure may, however, be much greater in the path of the auroral beams, since, as Prof. A. S. Herschel suggests, electrical repulsion may carry air or other matter up to a great height. A similar effect is observed in the so-called vacuum tubes, in which the pressure becomes much greater in the narrow central part, while the discharge is passing. It is found that the apparent altitude of the auroral corona is always a little less than that indicated by the dipping needle, owing to the curvature of the lines of magnetic force, or, in other words, because its altitude corresponds with the inclination of the parallel of latitude over which it is actually situated; and Galle has suggested (*Pogg. Ann.*, cxlvi. 133), that from this divergence the height may be calculated, and, indeed, gives a series of heights so determined, which do not differ materially from Prof. Newton's. It is, however, doubtful if the position of these coronæ, and consequently the value of the small angle (not more than 4° or 5°), admit of sufficiently accurate determination for such a use.

Spectroscopic observations.

Early observers, and especially Mr Canton, conjectured that the aurora was an electric discharge in the rarefied upper atmosphere, and the resemblance between it and the phenomena exhibited by discharges in an air-pump vacuum confirmed the idea. Recent spectroscopic observations have thrown some little doubt on this conclusion, or at least have shown that there is still a mystery left unexplained. When the light of any glowing gas is analysed by the prism, it is found to consist of a series of coloured lines and bands, of which the number and position is dependent on the nature of the gas, and which is called its spectrum. The light of the aurora gives a spectrum usually consisting of a single line in the greenish yellow, which does not coincide with a principal line of any known substance,—a spectrum totally different from those of the gases of the atmosphere. Besides this line there is occasionally visible a sharp line in the red, and several fainter and more refrangible bands. The following table includes most of the principal determinations of the auroral lines, which have hitherto been published:—

	WL.	Observer.	Remarks.	Mean WL.	Prob. Error.
1	6297	Vogel	±14. Bright red line only occasionally visible	6303	±8·1
	6279	Zöllner			
	6350	Ellery			
	6290	Oettingen	±40		
	6300	C. Piazzi Smyth			
2	5567	Angström		5569	±2·9
	5569	Vogel	±2		
	5571		±0·92		
	5570	Winlock			
	5548	Oettingen	±30		
	5545	Struve			
	5569	N. German Polar Expedition			
	5570	Peirce			
	5573	Respighi			
	5579	C. Piazzi Smyth			
	5600	Ellery			

	WL.	Observer.	Remarks.	Mean WL.	Prob. Error.
3	5340	Winlock		5342	±1·6
	5399	Vogel			
	5315	Peirce			
	5320	Alvan Clark			
4	5238	Vogel	±9	5214	±0·4
	5205	Peirce			
	5200	Winlock			
	5200	C. Piazzi Smyth			
	5235	Lemström			
	5210	Angström			
5	5189	Vogel		5161	±9·7
	5120	Oettingen	±22		
	5165	Backhouse			
	5170	Barker			
6	5004	Vogel	±3	4984	±1·1
	4930	Oettingen	±21		
	5015	Backhouse			
	5020	Barker			
	4950				
	4990				
7	4870	Angström		4823	±9·3
	4800	C. Piazzi Sm			
	4850	Clark			
	4820	Barker			
8	4694	Vogel	Broad band somewhat fainter in the middle. ±3	4667	±·8
	4663				
	4629				
	4640	C. Piazzi Smyth			
	4705	Barker			
	4720	Angström			
	4694	Lemström			
	4660	Oettingen	±25		
	4625	Backhouse			
	4640	Peirce			
9	4310	Peirce		4299	±9·3
	4240	Oettingen			
	4305	Backhouse			
	4350	Clark			
	4310	Barker			
	4262	Lemström			
	4320	C. Piazzi Smyth			
	4110	Lemström			

Vogel remarks that the line at 5569, which is often the only one visible, as well as the faint band at 4667, become noticeably fainter when the red line is visible, while under the same circumstances that near 5189, as well as the red line, is very brilliant. This fact, which has also been noted by other observers, makes it almost certain that the auroral spectrum is not a simple one, but is derived either from two or more sources, or from the same source under very varying conditions. Angström says (*Nature*, x. 211)—

"It may be assumed that the spectrum of the aurora is composed of *two* different spectra, which, even although appearing sometimes simultaneously, have in all probability different origins. The one spectrum consists of the homogeneous yellow light which is so characteristic of the aurora, and which is found even in its weakest manifestation. The other spectrum consists of extremely feeble bands of light, which only in the stronger aurora attain such intensity as enables one to fix their position even approximately. As to the yellow line in the aurora, or the one-coloured spectrum, we are as little able now as when it was first observed to point out a corresponding line in any known spectrum. True, Piazzi Smyth (*Comptes Rendus*, lxxiv. 597) has asserted that it corresponds to one of the bands in the spectrum of hydrocarbons; but a more exact observation shows that the line falls into a group of shaded bands, which belong to the spectrum, but almost midway between the second and third. Herr Vogel has observed that this line corresponds to a band in the spectrum of rarefied air (*Pogg. Ann.*, cxlvi. 582). This is quite true, but in Angström's opinion is founded on a pure misconception. The spectrum of rarefied air has in the yellow-green part seven bands of nearly equal strength, and that the auroral line corresponds with the margin of one of these bands, which is not even the strongest, cannot be anything else than merely accidental."

Angström's own view is that this line is due to fluorescence or phosphorescence, and he remarks that "since fluorescence is produced by the ultra-violet rays, an electric discharge may easily be imagined, which though in itself of feeble light, may be rich in ultra-violet rays, and therefore in a condition to cause a sufficiently strong fluorescence. It is also known that oxygen is phosphorescent, as also several of its compounds." We are, however, just as ignorant of any body which would give such a light by phosphorescence or fluorescence as by ignition, and it seems more probable that the light may be due to chemical action. It is assumed by Angström that water vapour is necessarily absent in the higher atmosphere on account of the cold, but when we remember that its molecular weight is lighter than that of oxygen in the proportion of 9 to 16, it is not unlikely that it may attain great elevations under the very low tensions that prevail at such heights, and it is possible also that both it and other bodies may, by electric repulsion in the auroral beams, be carried up much above the level which they would attain by gravity. If, then, electric discharges take place between the small sensible particles of water or ice in the form of mist or cirrus, as Silbermann has shown to be likely, surface decomposition would ensue, and it is highly probable that the nascent gases would combine with emission of light. It has been almost proved in the case of hydrogen phosphide that the very characteristic spectrum produced by its combustion is due neither to the elements nor to the products of combustion, but to some peculiar action at the instant of combination, and it is quite possible that, under such circumstances as above described, water might also give an entirely fresh spectrum.

It is, perhaps, proper to mention that H. R. Procter found an apparent coincidence by often repeated direct comparison with a band frequently seen both in air and oxygen tubes, which he eventually succeeded in tracing with tolerable certainty to some form of hydrocarbon. The comparison spectroscopes were only of low dispersion, but on more accurate measurement of the carbon band it was found that, though more refrangible than the first band of citron acetylene (candle-flame), it was still less so than careful measurement assigns to the aurora. In addition, the band was shaded towards the violet, which is not the case with that of the aurora, though with feeble light it seemed like a line.

If, leaving the citron line, we pass on to the feeble spectrum towards the violet, we shall obtain more hopeful coincidences. Angström thinks that three of the bands correspond with the three brightest bands of the violet aurora of the negative pole in rarefied air, and has tried to reproduce the conditions of the aurora on a small scale. He says—

"Into a flask, the bottom of which is covered with a layer of phosphoric anhydride, the platinum wires are introduced, and the air is pumped out to a tension of only a few millimetres. If the inductive current of a Ruhmkorff coil be then sent through the flask, the whole flask will be filled, as it were, with the violet light, which otherwise proceeds only from the negative pole, and from both electrodes a spectrum is obtained consisting chiefly of shaded violet bands. If this spectrum be compared with that of the aurora, Angström thinks the agreement between the former and some of the best established bands of the latter is satisfactory.

Lines.		Wave Lengths.		
Of the aurora spectrum,	according to Barker,	431	470·5	...
	,, Vogel,	..	469·4	523·3
	,, Angström,	..	472	521
	,, Lemström,	426·2	469·4	523·5
	Mean,	428·6	470·3	522·6
Of the spectrum of the violet light,		427·2	470·7	522·7

In the neighbourhood of the line 469·4 Herr Vogel has, moreover, observed two weak light-bands, 466·3 and 462·9 (?). The spectrum of the violet has also two corresponding shaded bands, 465·4 and 460·1.

"Should the aurora be flamy, and shoot out like rays, there is good reason for assuming a disruptive discharge of electricity, and then there ought to appear the strongest line in the spectrum of the air, the green, whose wave-length is 500·3. Precisely this has actually been observed by Vogel, and has, moreover, been seen by Angström and others. Finally, should the aurora be observed as it appears at a less height in the atmosphere, then are recognised both the hydrogen lines and also the strongest of the bands of the dark-banded air-spectrum. There are found also again nearly all the lines and light-bands of the weak aurora spectrum whose position has with any certainty been observed."

With regard to the red line, which is sometimes perfectly sharp and well defined, and occasionally, though very rarely, even as bright as the citron line, scarcely even a plausible theory has been hazarded. That it is not the C line of hydrogen is certain, as they have been directly compared, and are widely separated; and none of the air lines near its position are at all comparable to it in brightness. Vogel thinks it may "correspond with the first system of lines in the spectrum of nitrogen (6620 to 6213), and that probably only the bright part of this group of lines is visible on account of the extreme faintness of the aurora." This, however, cannot be the case, since the present writer has seen it both bright and sharp. Vogel points out that the line near 5189 closely corresponds to an oxygen line of that wave-length which is bright and constant under very different conditions of pressure and temperature. He states that the faint line near 5390 corresponds in like manner to a nitrogen line. He points out that, though the correspondences with the iron lines are very striking, but little weight can be laid on the fact, since many of the brightest lines of the iron spectrum do not appear. The following table gives the principal iron lines (Thalén) and the auroral ones; and it will be seen that the former are so abundant that coincidences could scarcely fail:—

Iron.	Brightness.	Aurora.	Iron.	Brightness.	Aurora.	Iron.	Brightness.	Aurora.
6490	6		5546	10		5167	8	5161
6389	10		5429	10		5139	8	
6300	6	6303	5405	8		5061	8	
6245	8		5403	8		5049	8	
6230	8		5396	8		4957	10	4984
6190	8		5392	8		4920	10	
6136	8		5371	10		4918	8	
6065	8		5346	8	5342	4890	10	
5658	10		5339	8		4871	8	
5614	10		5327	10		4870	8	4823
5602	10		5323	8		4415	10	4667
5597	10		5283	8		4404	10	
5591	8		5269	10		4383	10	
5586	10		5268	10		4325	10	
5575	8		5266	8		4307	10	4299
5572	10		5232	10		4271	10	
5569	8	5569	5226	10	5214	4251	10	
5545	10		5192	8		4250	10	

Angström asserted some years since that he had detected the principal line of the aurora in the spectrum of the zodiacal light, but he appears to have been misled by a faint aurora, for more recent observers, and notably Prof. C. Piazzi Smyth, Mr Backhouse, and A. W. Wright (*Sill. Jour. of Sc.*, viii. 39), have found that the spectrum of the zodiacal light is continuous and quite analogous to that of twilight or faint starshine, and polariscope observations prove that it is mostly reflected. The very faint line positioned by Alvan Clark at 5320 has been said by Winlock to coincide with the principal coronal line 5322. The position of the auroral line is uncertain; and even if it were accurate, a single doubtful coincidence with a faint line is not the least proof of identity.

We have already remarked the manifest relation between the forms and position of auroræ and the earth's lines of magnetic force, and in addition to this have noted the disturbance of the magnetic needle during auroral displays. It is not, however, at such times only that the magnetic elements are subject to variation; the total force, declination, and inclination, all are constantly varying both regularly with the hours of the day and the seasons of the year, and irregularly at uncertain times. The irregular oscillations when violent are called magnetic storms, and it must be noted that auroral display never takes place except during such disturbances, although a large proportion of the most remarkable magnetic storms are unaccompanied by visible auroræ.

Franklin, who was one of the first observers of this relation (at Fort Enterprise, 64° 30′ N., 113° 10′ W.), says of the magnetic needle,—"The motion communicated to it was neither sudden nor vibratory. Sometimes it was simultaneous with the formation of arches, prolongation of beams, or certain other changes of form or action of the aurora. But generally the effect of these phenomena upon the needle was not visible immediately, but in about half an hour or an hour the needle had attained its maximum of deviation. From this its return to its former position was very gradual, seldom regaining it before the following morning, and frequently not until the afternoon, unless it was expedited by another arch of the aurora operating in a direction different from the former one."

"The arches of the aurora," he adds, "most commonly traverse the sky nearly at right angles to the magnetic meridian, but deviations from this direction, as has already been stated, were not rare; and I am inclined to consider that these different positions of the aurora have considerable influence on the direction of the needle. When an arch was nearly at right angles to the magnetic meridian, the motion of the needle was towards the west. This westward motion was still greater when one extremity of the arch bore 301°, or about 59° to the west of the magnetic north, that is, when the extremity of the arch approached from the west towards the magnetic north. A westerly motion also took place when the extremity of an arch was in the true north, or about 36° to the west of the magnetic north, but not in so great a degree as when its bearing was about 301°. A contrary effect was produced when the same end of an arch originated to the southward of the magnetic west, viz., when it bore from 245° to 234°, and of course when its opposite extremity approached nearer to the magnetic north. In these cases the motion of the needle was towards the east. In one case only a complete arch was formed in the magnetic meridian, in another the beam shot up from the magnetic north to the zenith; and in both these cases the needle moved towards the west.

"The needle was most disturbed on February 13th, P.M., at a time when the aurora was most distinctly seen passing between a stratum of clouds and the earth, or at least illuminating the face of the clouds opposed to the observer. This and several other appearances induced me to infer that the distance of the aurora from the earth varied on different nights, and produced a proportionate effect on the needle. When the light shone through a dense hazy atmosphere, when there was a halo round the moon, or when a small snow was falling, the disturbance was generally considerable; and on certain hazy, cloudy nights the needle frequently deviated in a considerable degree, although the aurora was not visible at the time. Our observations do not enable us to decide whether this ought to be attributed to an aurora concealed by a cloud or haze, or entirely to the state of the atmosphere. Similar deviations have been observed in the day-time, both in a clear and cloudy state of the sky, but more frequently in the latter case. An aurora sometimes approached the zenith without producing any change in the position of the needle, as was more generally the case; whilst at other times a considerable alteration took place although the beams or arches did not come near the zenith. The aurora was frequently seen without producing any perceptible effect on the needle. At such times its appearance was that of an arch, or an horizontal stream of dense yellowish light, with little or no internal motion. The disturbance in the needle was not always proportionate to the agitation of the aurora, but it was always greater when the quick motion and vivid light were observed to take place in a hazy atmosphere. In a few instances the motion of the needle was observed to commence at the instant a beam darted upwards from the horizon; and its former position was more quickly or slowly regained according to circumstances. If an arch was formed immediately afterwards, having its extremities placed on opposite sides of the magnetic north and south to the former one, the return of the needle was more speedy, and it generally went beyond the point from whence it first started."

Speaking of the aurora of May 13, 1869, M. Lamont of Munich says (*Comptes Rendus*, lxviii. 1201)—

"1. During 40 years I have only seen seven or eight auroræ at Munich, and this small number is insufficient for a study of the characters of the phenomenon.

"2. Auroræ, whether visible at Munich or not, are always accompanied by magnetic perturbations.