

Treasurer.

Horace Jayne.

Councillors for three years.

Henry C. Baird, Isaac J. Wistar, Jacob M. DaCosta.

Councillor for one year, to fill an unexpired term.

George F. Edmunds.

Dr. I. Minis Hays was nominated for Librarian for the ensuing year.

Prof. Cleveland Abbe read a paper on "The Accepted Altitude of the Aurora Borealis."

Mr. Sachse and Mr. Cook offered some remarks in discussion.

Dr. T. J. J. See presented a paper for the *Transactions* on "The Evolution of the Stellar Systems," which was discussed by Prof. Doolittle, Prof. Snyder, Dr. See and Prof. Abbe.

The Society was adjourned by the presiding member.

THE ALTITUDE OF THE AURORA ABOVE THE EARTH'S SURFACE.

BY CLEVELAND ABBE.

(Read January 7, 1898.)

During the past three centuries numerous observers and physicists, astronomers and magneticians have endeavored to contribute to our knowledge of the altitude of the region whence the auroral light proceeds, and still the greatest diversity of opinion seems to prevail on this subject. Some observers have seen the light in such positions between themselves and neighboring objects as to demonstrate that the aurora, like the lightning, descends to the very surface of the earth and may even be entirely confined to the lowest stratum: prominent among these are Captain Parry, Sir James Clark Ross and Sir John Ross, his uncle, Dr. Walker and Prof. J. P. Lesley.

Others, such as Dr. Richardson, Sir John Franklin, Silbermann, have seen it so located among the clouds that its origin must be placed at or below their level and, therefore, within a few thousand feet of the earth's surface. On the other hand, those who have calcu-

lated the altitudes of specific beams and arches by trigonometrical or equivalent methods have generally found figures indicating altitudes between twenty and a hundred miles. Perhaps the highest altitudes that have been deduced were the following: Dalton, 150 miles; Loomis, 400 to 600; Bergman, 468; Boscovich, 825; Fournierius, 1006; Twining, 1100; Boller, 2000 kilometers, or 1243 miles.

Those who delight in numerical calculations accept these larger altitudes and content themselves with saying that the altitude of the aurora ranges from 50 miles upward to 1000. The experimental physicists, by studying the analogies between the auroral light and the discharge of electricity through vacuum tubes, have shown that the auroral phenomena harmonize in part at least with those observed in vacua such as might occur at moderate altitudes. Thus, Miller and De La Rue give altitudes of from ten to forty miles. Espy and Bache maintained that observers a few miles apart did not and could not have observed the same arches. The most careful observers have in many cases defended the accuracy of the observations made under circumstances that admit of no doubt that the auroral light in the free atmosphere often emanates from points within a few yards of the observer.

Lemstrom has sought to reconcile the diverse conclusions by maintaining that while many auroras are quite high up and belong to the upper air, yet those in extreme northern latitudes most generally belong to the lowest strata and follow the unevenness of the ground, appearing as glows around the mountain top, or as rays directed toward prominent objects.

The object of the present paper is to study some of the numerous observations, calculations and opinions bearing on the nature and the altitude of the auroral light. We shall not especially consider the electrical origin, or the source of the electricity, but simply acquiesce in the universal conviction that it really is one form of electrical discharge, our main object being to ascertain whether we can in any way definitely fix its *locus* in the atmosphere.

The most instructive method of procedure consists in taking up the consideration of a number of authorities in chronological order, by which means one is led to appreciate the slow progress of knowledge and the difficulty which many investigators have felt, from time to time, in giving up preconceived views without having anything better to accept in their place. There is nothing more diffi-

cult than to recognize the fact that all our ideas are wrong, and that we are wholly in the dark with regard to the nature of that which our eyes behold so plainly. How many thousands of years elapsed before modern science gave us any clue to the true nature of the rainbow, and how difficult it has been to eradicate from our textbooks the crude ideas of Descartes, Huyghens and Sir Isaac Newton which made the rainbow to be a phenomenon of dispersion and substitute the correct view of Thomas Young, who showed it to be a phenomenon of interference.

Possibly we must go through a similar series of changes in our views with regard to the auroral light until we recognize that each observer sees his own aurora as a so-called optical illusion.

There are several forms of optical illusion that are evidently connected with the aurora. Some of these were recognized long since, while others are still deceiving our senses and perplexing our calculations.

As we pursue our reading chronologically, among the different authorities, we shall perceive how one after another is led to suspect and fully recognize some one or other of these optical or perspective illusions, while others, inattentive thereto, plunge deeper into misleading calculations. If, at the end of our consideration of the subject, we sum up all that has been shown to be probable or demonstrated to be true, we shall almost necessarily conclude that the determination of the altitude of the aurora is a much more delicate problem and perhaps also a more indefinite problem than we have hitherto believed.

After reviewing the literature of the subject since the time of Halley, we find that the methods of determining the altitude of specific features of the aurora may be enumerated as follows: (1) Parallax method; (2) Galle's first method; (3) Galle's second method; (4) Bravais' method of amplitudes and its modifications by Fearnley, Newton, Nordenskiöld and Bergmann; (5) Bravais' method by the apparent breadth of the arch; (6) Bravais' velocity method; (7) my method, by the simultaneous motion of waves at the zenith and beams above an arch; (8) Gyllenskiöld's method, by the apparent length of the auroral beam.

All these agree in one fundamental assumption, that the observed beams and arches have an individual existence and a definite *locus*. But this assumption is negatived by the equal frequency of negative and positive parallaxes whenever the parallax method is applied.

The only conclusion possible is that the observers do not see the same object, partly because the aurora is too low down and partly because there are optical illusions due to alignment. We are viewing a luminous sheet which is folded and refolded. We are also viewing a great collection of bright beams and bright pencils of light parallel to each other like the trees in a forest. Every slight change in the position of the observer alters the collective appearance of the pencils and the folds. The only method of determining parallaxes with any confidence consists in requiring two or more observers to start at the same point, fixing their attention upon one feature; separate to a short distance in opposite directions and return until they have satisfied themselves that the illusions due to perspective and alignment are not sufficient to nullify the influence of parallax.

Stated Meeting, January 21, 1898.

Vice-President SELLERS in the Chair.

Present, 14 members.

Mr. Alden Sampson, a newly elected member, was presented to the Chair and took his seat.

Acknowledgments of election to membership were received from Richard Olney, William H. Dall, Leroy W. McCay.

Mr. Rosengarten read an obituary notice of the late Treasurer, J. Sergeant Price, Esq.

Dr. Hays was elected Librarian for the ensuing year.

The appointment of the Standing Committees was referred to the President.

The following papers were presented:

For the *Transactions*:

Posthumous papers of the late Dr. Harrison Allen on

"The Glossophaginæ" and on

"The Skull and Teeth of the Ectophylla alba."

For the *Proceedings*:

"Specializations in the Lepidopterous Wing—Pieris-Nymphalidæ," by Mr. A. R. Grote.



Abbe, Cleveland. 1898. "The Altitude of the Aurora above the Earth's Surface." *Proceedings of the American Philosophical Society held at Philadelphia for promoting useful knowledge* 37(157), 4–7.

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