STÖRMER'S WORK ON THE PHYSICS OF THE AURORA.[1]

Reviewed by P. G. NUTTING.

With the recent advances in our knowledge of luminescence and electrical effects in rarified gases, hypotheses of auroral formation have become fewer in number and more specific in detail. The spectroscope and transit long ago showed that the aurora is an excitation to luminescence of the upper portions of the Earth's atmosphere. Further study with the spectroscope showed that the luminescence is such as could be caused only by a bombardment of cathode rays, corpuscles, or negative electrons, whatever they may be called. If the light had been caused by a steady current of electricity or by an electric wave it would be reddish orange instead of bluish white in color and would exhibit an altogether different spectrum. A disruptive discharge like lightning would produce a yellowish white light, with still a third spectrum composed of heavy lines instead of bands.

In order to account for the necessary cathode rays, Birkeland[2] in 1896 supposed them to be emitted by the Sun much as they are emitted by a hot platinum wire or other heated body. Proceeding to the Earth with about one-third the velocity of light, these particles would be entrapped by the earth's magnetic field and excite the outer atmosphere to luminescence.

Birkeland, however, did not consider his theory sufficient to account for the known structure and variability of the aurora. In 1900 he advanced a second theory[3] according to which he supposed the cathode rays produced within the atmosphere by other rays from the Sun. In this manner he obtained more unknown variables as factors in the aurora but left the matter in such an unsatisfactory state that three other theories of the aurora made their appearance.

Arrhenius[4] in 1900 supposed the necessary cathode rays to be produced in the Earth's atmosphere by particles larger than molecules emitted by the Sun and propelled by radiation pressure. Nordmann[5] in 1903 advanced the theory that they were produced by electric waves

[1] CARL STÖRMER. Sur les trajectoires des corpuscles electrises dans l'espace sous l'action du magnetisme terrestre avec application aux aurores boreales. Arch. Sc. Phys. Genève, July, Aug., Sept., Oct., 4 periode, v. 24, 1907, pp. 140 with 2 pl. Compt. Rend., 142, 1580–1583; 143, 140–142, 1906. *Cf.* also vol. IX, *T. M*, p. 149 and CARL STÖRMER: sur un probléme relatif au mouvement des corpuscules électriques dans l'espace cosmique, (Videnskabs-selskabets skrifter. I. Math.-maturv. Kl. 1907, No. 4) pp. 10, 27 1/2 X 18 1/2. Kritiania 1907.

[2] K. BIRKELAND, Geneva Arch. des Sci. (4), 1, 497, 1896.

[3] K. BIRKELAND, Geneva Arch. des Sci. (4), 12, 478, 1901.

[4] SVANTE ARRHENIUS, Phys. Zeit., 2, 81, 97, 1901.

[5] C. NORDMANN, J. de Ph., 3, 282, 1904.

from the Sun ionizing the upper atmosphere. Paulsen[6] later put forth a theory similar to the second of Birkeland's but providing for an accumulation of "auroral material", a mixture of ionized air and cathode rays, produced by cathode rays and ultra violet light from the Sun.

Finally Störmer, in the paper here under review, taking up Birkeland's first theory, worked out mathematically the trajectories of cathode rays projected into such a magnetic field as that of the Earth. He showed that so great is the variation in path produced by slight differences in the velocity and original direction of such particles that Birkeland's simple first theory is ample to account for observed phenomena.

A negative electron projected into a magnetic field in an equatorial plane, moves in a curved path the form of that described by a point on a circle rolling on the inside of a larger circle. The stronger the magnetic field the smaller is the generating circle. Shot obliquely into a field, such a particle moves in a spiral path and if the field be convergent the spiral path is conical. The particle moves along the cone to where the field reaches a certain intensity and back again on another cone with its axis slightly displaced from the first. Störmer shows that in the Earth's field the trajectory is the form of a wire wound on a cow's horn with its apex towards a magnetic pole.

Cathode rays would not be emitted freely at all times from all parts of the surface of the Sun on account of the residual positive field. We should expect them to break forth in limited clouds during severe electrical storms in connection with Sun spots. A small group just reaching the Earth after sunset in winter would strike the Earth's field tangentially in an oblique direction, move on a curved spiral path toward the north pole, reverse and move toward the south pole, again reverse and so on until absorbed by the atmosphere. On each trip north or south they would move in a different group of paths, hence the serrated structure of the simple aurora. Linear velocity and hence luminescence produced would be greatest at the north and south ends of the paths. The trip from north to south would occupy from about half a second to five seconds according to the inclination and original velocity of the rays. This would be a plausible origin of the magnetic fluctuations observed during the smaller but more active displays.

More extended clouds of electrons from the Sun would produce draped and diffused auroras. More intense displays might even be accompanied by ordinary electrical conduction and hence the reddish tints sometimes observed.

All things considered, the Birkeland–Störmer theory is by far the most satisfactory thus far advanced, both in its simplicity and in its explanation of widely varied phenomena. It is indeed the only theory thus far advanced that is free from radical objections.

[6] ADAM PAULSEN, Bull. Acad. Sci. Danemark, 2, 109, 1906. *Cf.* vol XII, *T. M.*, p. 94.