Kristian Birkeland (1867 - 1917)

the Almost Forgotten Scientist

and Father of the Sun-Earth Connection

PÅL BREKKE

Norwegian Space Centre

ISWI Workshop, Boston College, 31 July - 4 August 2017

The Young Kristian Birkeland

Olaf Kristian Birkeland was born 13 December 1967.

Early on Birkeland was interested in magnetism and already as a schoolboy he had bought his own magnet with his own money.

He used the magnet for many surprising experiments and practical jokes - often irritating his teachers

Birkeland’s Early Career

Birkeland became a certificate teacher at the University of Kristiania at only 23 years old and graduated with top grades.

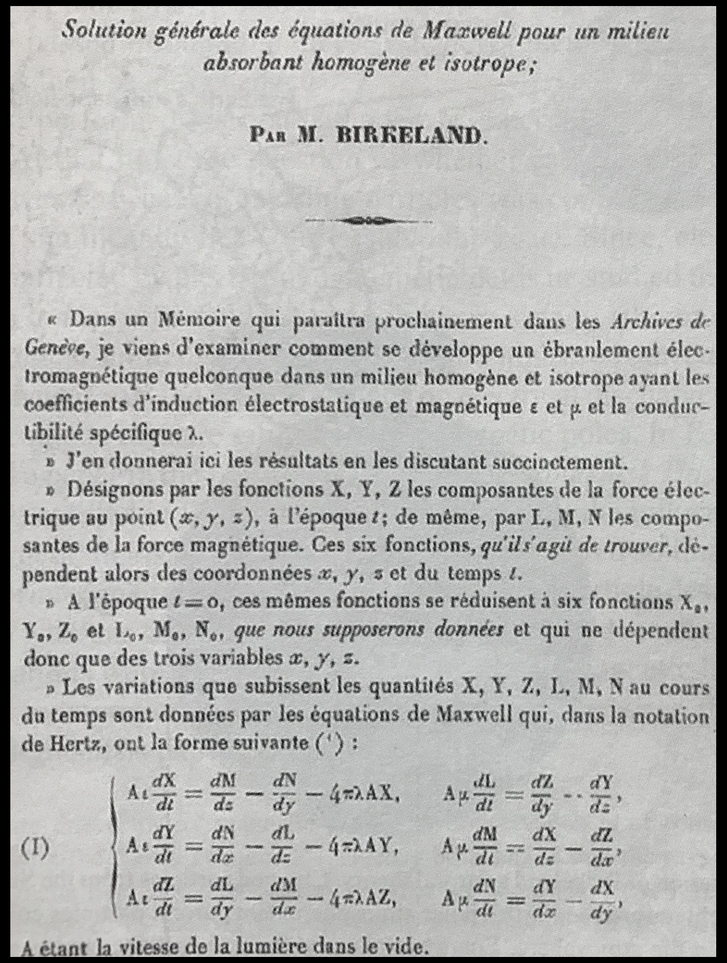
In 1896 Birkeland was elected into the Norwegian Academy of Sciences at only 28 years old.

Two years later he became a professor in Physics - quite unusual at that young age at that time (was called «the boy professor»).

Photograph of Kristian Birkeland on Karl Johans Gate, (Oslo) in 1895 taken by student Carl Størmer, using a concealed camera. (source: UiO)

Birkeland - Electromagnetic Waves

- Birkeland did laboratory experiments on electromagnetic waves in 1890 and first publication came in 1892 with some ground breaking results.
- In 1893 he focused on the energy transported by these waves.
- In 1895 Birkeland published his most important theoretical paper. He provided the first general solution of Maxwell's equations for homogeneous isotropic media.



Solution générale des équations de Maxwell pour un milieu absorbant homogène et isotrope;

PAR M. BIRKELAND.

« Dans un Mémoire qui paraîtra prochainement dans les *Archives de Genève*, je viens d'examiner comment se développe un ébranlement électromagnétique quelconque dans un milieu homogène et isotrope ayant les coefficients d'induction électrostatique et magnétique ε et μ et la conductibilité spécifique λ.

» J'en donnerai ici les résultats en les discutant succinctement.

» Désignons par les fonctions X, Y, Z les composantes de la force électrique au point (x, y, z), à l'époque t; de même, par L, M, N les composantes de la force magnétique. Ces six fonctions, *qu'il s'agit de trouver*, dépendent alors des coordonnées x, y, z et du temps t.

» A l'époque $t = 0$, ces mêmes fonctions se réduisent à six fonctions X_0, Y_0, Z_0 et L_0, M_0, N_0, *que nous supposerons données* et qui ne dépendent donc que des trois variables x, y, z.

» Les variations que subissent les quantités X, Y, Z, L, M, N au cours du temps sont données par les équations de Maxwell qui, dans la notation de Hertz, ont la forme suivante (1) :

$$(I)\quad \begin{cases} A\varepsilon\dfrac{dX}{dt} = \dfrac{dM}{dz} - \dfrac{dN}{dy} - 4\pi\lambda AX, & A\mu\dfrac{dL}{dt} = \dfrac{dZ}{dy} - \dfrac{dY}{dz}, \\ A\varepsilon\dfrac{dY}{dt} = \dfrac{dN}{dx} - \dfrac{dL}{dz} - 4\pi\lambda AY, & A\mu\dfrac{dM}{dt} = \dfrac{dX}{dz} - \dfrac{dZ}{dx}, \\ A\varepsilon\dfrac{dZ}{dt} = \dfrac{dL}{dy} - \dfrac{dM}{dx} - 4\pi\lambda AZ, & A\mu\dfrac{dN}{dt} = \dfrac{dY}{dx} - \dfrac{dX}{dy}, \end{cases}$$

A étant la vitesse de la lumière dans le vide.

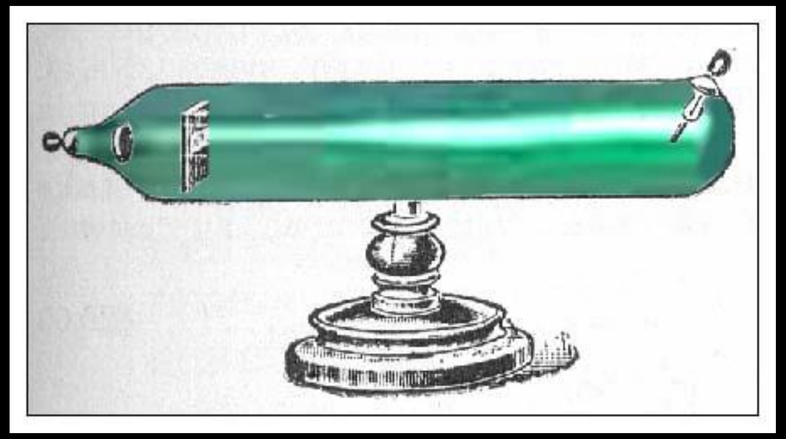
First page of Birkeland's 1895 paper where he derived a general solution to Maxwell's equations

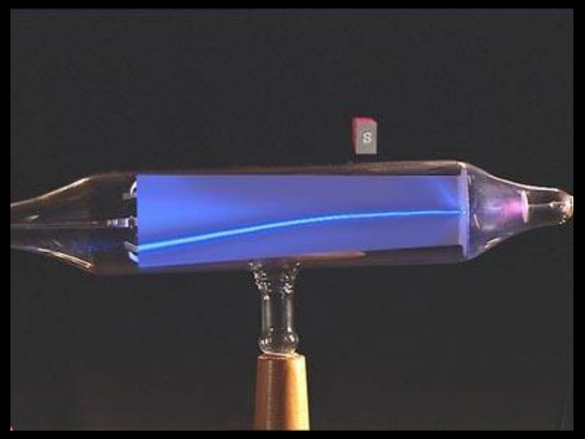
Birkeland - Cathode Rays

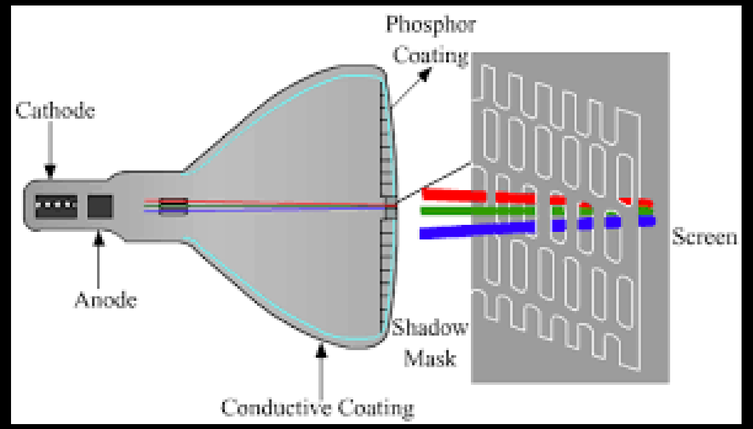
In 1895 he began pioneer studies of cathode rays, a stream of electrons in a vacuum tube that occurs through high voltage passing between negative and positive charged electrodes.

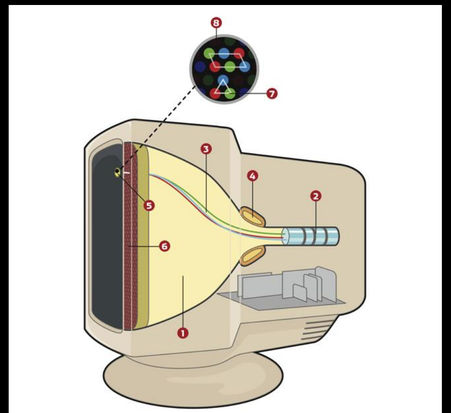
Birkeland concluded that the cathode rays consist of electrically charged particles and can be controlled by a magnetic field.

This would lead to his major scientific finding to explain the Northern Lights and its connection to the Sun.





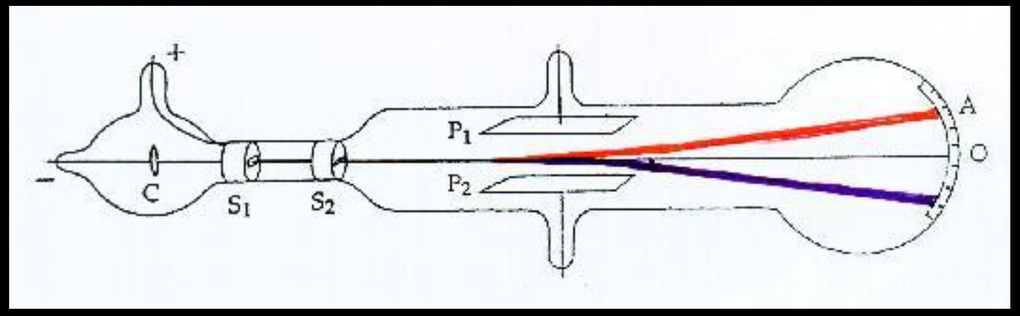




Birkeland - The Electron

Birkeland was probably close to discovering the electron. The English physicist Joseph J. Thompson made the discovery, basing his conclusions on experiments Birkeland had worked on.

Many have argued that German physicist Emil Weichert and Birkeland should have been recognised along with Thompson for the discovery of electrons. Thompson did however mention Birkeland's contribution in his Nobel-lecture.



Birkeland and X-rays

In 1895, the European newspapers were filled with articles about the «new kind of rays» discovered by Wilhelm C. Röntgen. He discovered the radiation by a coincident on 8 November 1885. They made a plate of fluorescent paint glow. The radiation was named X-rays - «unknown radiation»

Birkeland told he had observed this radiation before Röntgen did his discovery.

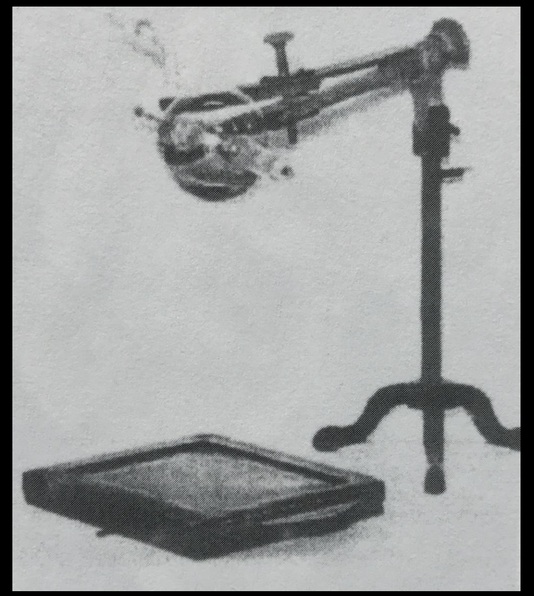
Røntgen tok et bilde av sin kones hånd
på slutten av 1885-tallet.

Birkeland and X-rays

Just a few months later Birkeland demonstrated X-rays at the University of Oslo (15 February 1896). A week later i did a public demonstration where his audience could see the effects if the «new rays». The same evening he also demonstrated artificial aurora.

Just prior to this some doctors had argued that X-rays would never have any greater importance for medical research or practical use in medicine.

In 1915 he planned to take a patent on a «radiation shirt» to treat cancer.



Birkelands first X-ray tube and photographic plate (1896)

Birkelands X-ray of professor Torups hand in 1896. Exposure time: 5 minutes

Birkeland - Other Interests

Radio Communication

Birkeland also conducted extensive radio wave experiments between 1908 and 1910 related to telegraph and telephone technology.

He took out seven patents on electromagnetic technology and together with Wallenberg and Sam Eyde he formed a small company called «Birkeland’s Patents in Wireless Telegraphy and Telephony».

Atomic Energy

In 1906 Birkeland sent two letters to Wallenberg brothers proposing to split atoms to create energy. Arguing that one get get more energy out of 1 kg matter than 100.000 kg coal.

Birkeland - the Inventor

Birkeland worked on many applications (spinn offs) of his research.

About 60 patents came from his creative production. This included mechanical hearing aid, power switches, harding of fats, redistilling and refining of crude oil.

We can also thank Birkeland for both caviar and margarine.

And his most famous patent - the electromagnetic gun

And he invented the electromagnetic cannon

No. 754,637. Patented March 15, 1904.

UNITED STATES PATENT OFFICE.

KRISTIAN BIRKELAND, OF CHRISTIANIA, NORWAY.

ELECTROMAGNETIC GUN.

SPECIFICATION forming part of Letters Patent No. 754,637, dated March 15, 1904.

Application filed January 2, 1902. Serial No. 88,189. (No model.)

To all whom it may concern:

Be it known that I, KRISTIAN BIRKELAND, a subject of the King of Sweden and Norway, residing at Christiania, Norway, (whose post-office address is the same,) have invented certain new and useful Improvements in Electromagnetic Guns; and I do hereby declare the

weighing about twenty-four pounds and having an inner diameter of nearly two miles and an outer diameter of four and one-half inches was drawn into the solenoid with a force of about one hundred and seventy pounds, when a current of two hundred and thirty amperes was sent through the solenoid. The

Birkeland - the Electromagnetic Cannon

Birkeland was regarded as one of the best experimental physicist of his time. And to find practical use of his research.

He developed the electromagnetic cannon - that he thought the military would buy. The banquet hall at the University of Oslo was filled with guests. Two ministers and Fritjof Nansen was observing from the front row.

The cannon was supposed to hurl a 10 kg bullet into a wall. However, the cannon shorted - and almost exploded. A large arc of light appeared.

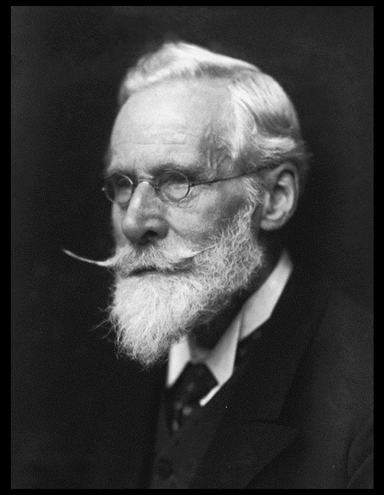
Birkelands electromagnetic cannon

Birkeland - the Industrial Man

The test firing was a failure, but it marked the beginning of the largest industrial adventure in Norwegian history.

A few years earlier Sir William Crookes alerted the scientific community to the scarcity of calcium nitrate in the world, one of the main ingredients in manufacturing fertiliser.

Crookes argued that if one solved this by retrieving nitrogen directly from the air, this would be one of the greatest inventions in the future and could save the world from starving.



Sir William Crookes

Birkeland - the Industrial Man

Birkeland notice a large arc of light and the smell of nitrogen during the short circuits. He patented the technique to extract nitrogen from air and together with Sam Eyde he developed the Birkeland-Eyde oven.

This was the start of Norsk Hydro - and by 1908 they produced 7000 tons. A few years later the capacity was 28.000 tons

Later this part of Hydro was renamed Yara - and is still the world biggest fertilising company.

Birkeland-Eyde-oven at Hydro

Hydro Patent no 1

Birkeland - «The Solar Wind»

Already in 1896 Birkeland made the important assumption that the Sun continuously sends out cathode rays (charged particles) as well as photons. He based this on the continuous appearance of northern lights in the far north.

Earlier Richard C. Carrington had suggested particles flowing from the Sun to the Earth during the flare in 1859.

And in 1910 Arthur Eddington suggested the existence of the solar wind without naming it.

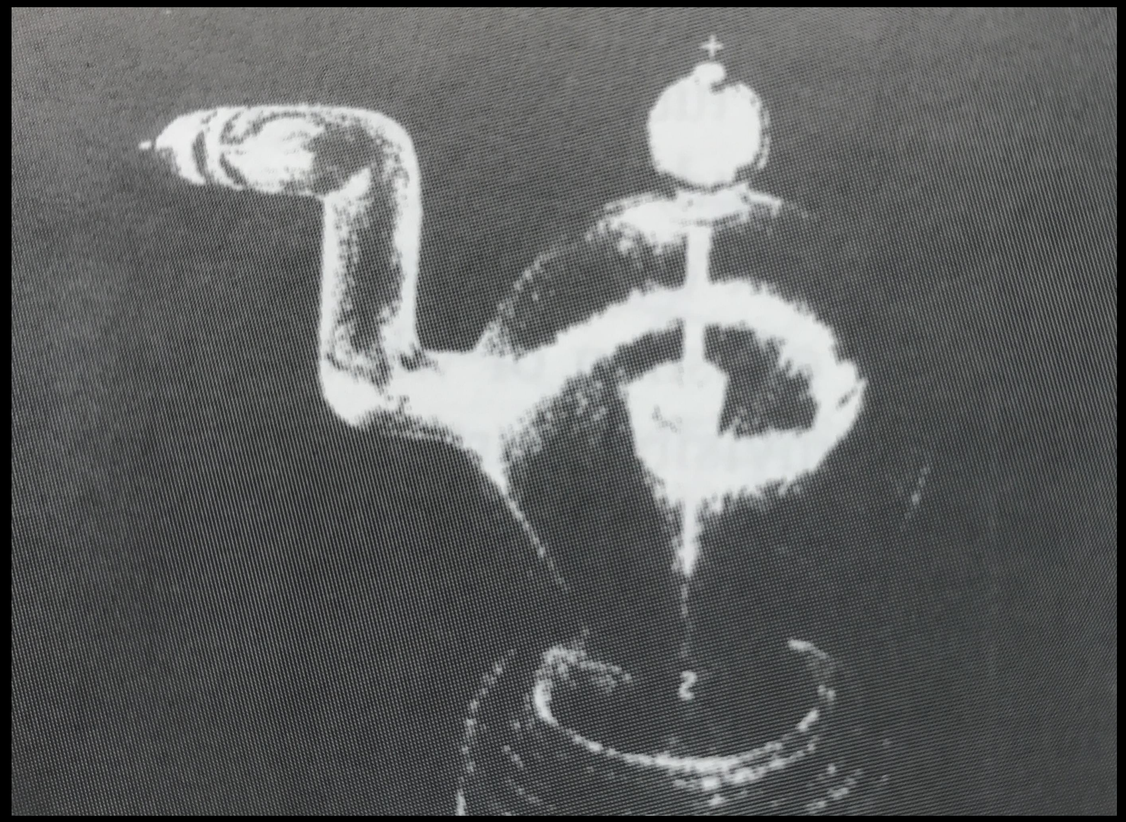
Birkeland was the first to suggest the ejected materiel from the Sun consisted of both ions and electrons.

He estimated the density if the interplanetary space to be about eight particles per cubic centimeter. This is remarkable close to the average density of the Solar wind measured today.

Birkelands Terrella-experiments

Birkeland made a series of different vacuum-tank experiments. The first ones were glas discharge tubes.

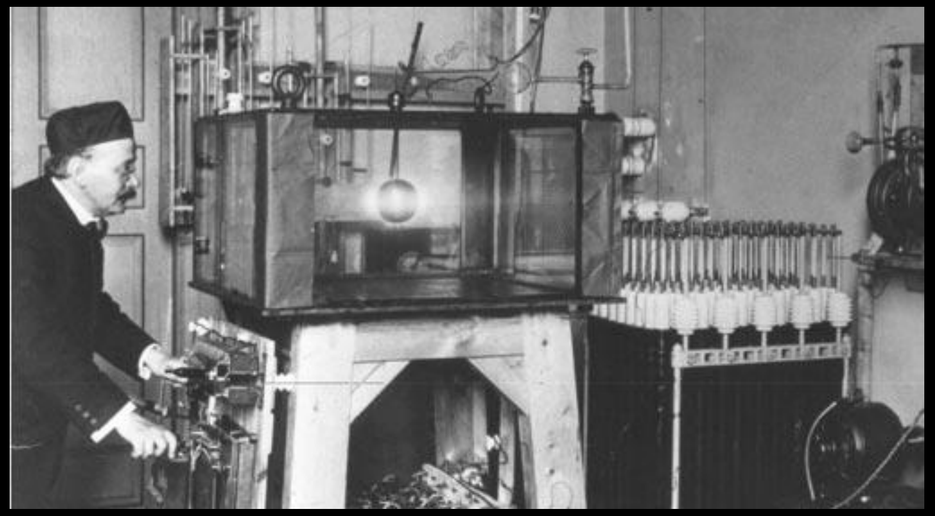
In 1896 he made his first artificial aurora inside a device Birkeland called an «auroral jar»



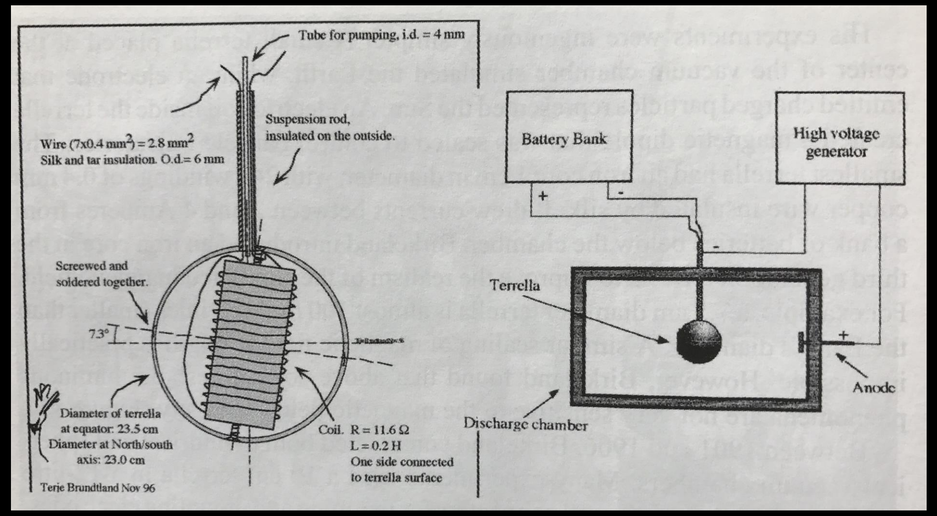
Birkelands Terrella-experiments

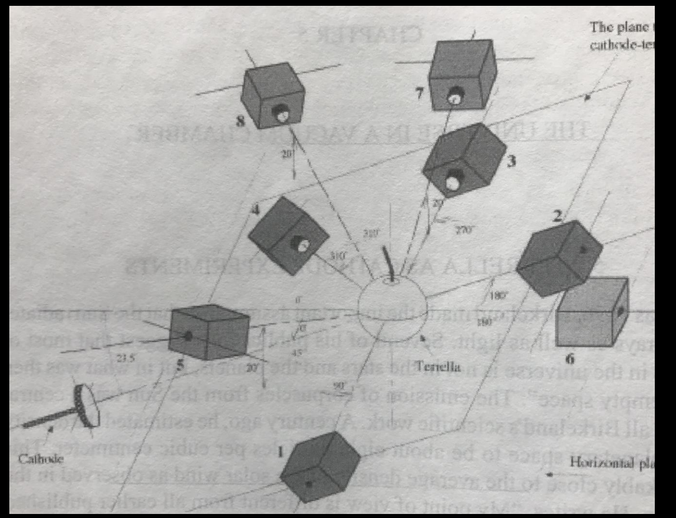
Using an electromagnet, he could create a magnetic field around the terrell mimicking Earth’s magnetosphere.

The atmosphere was a layer of fluorescent paint that would give off light when it was struck by charged particles.



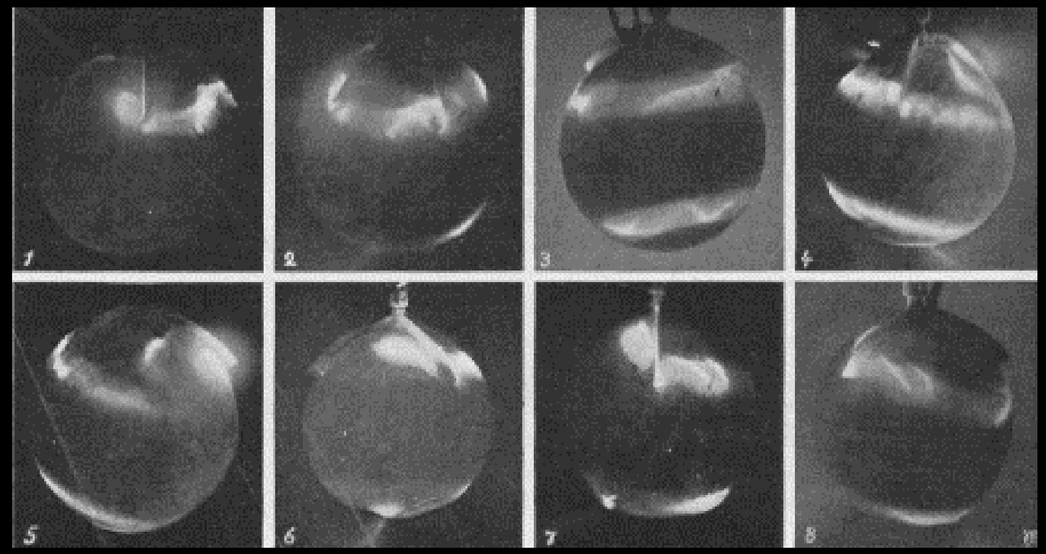
The voltage was 25.000 volt





Birkeland Currents

Birkeland also launched an idea that the same particles that create the northern lights set up a system of electrical currents in the Earth's atmosphere. Such flows could explain the magnetic disturbances observed during strong auroras.



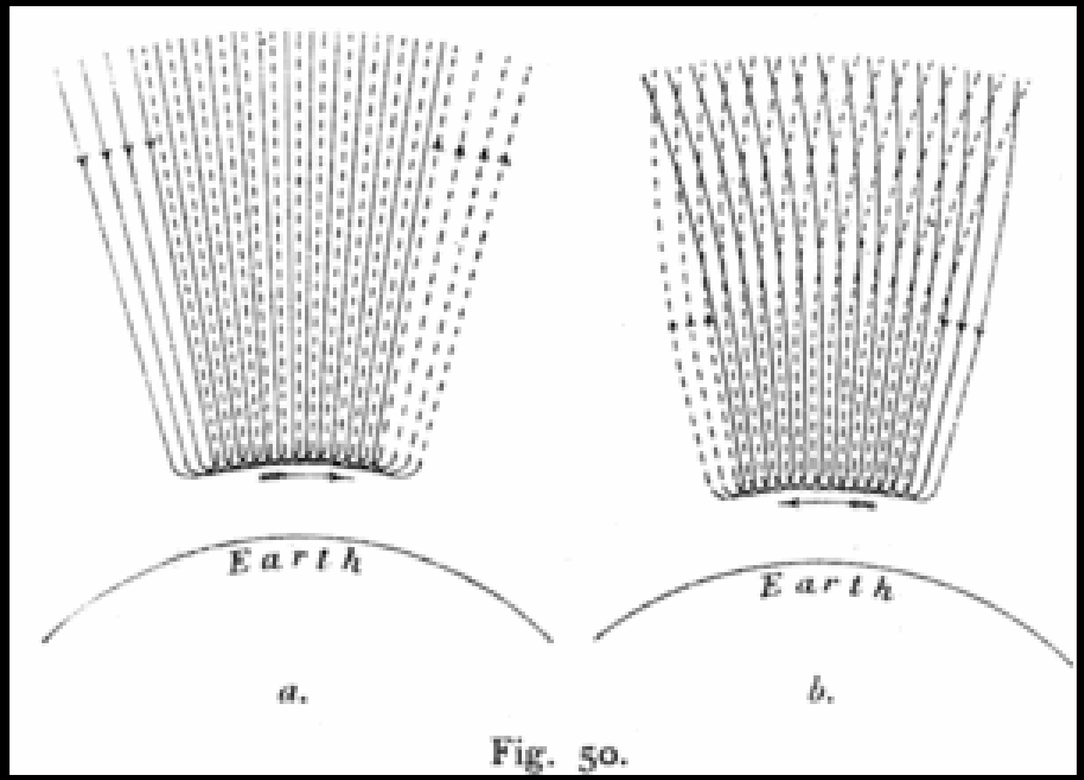


Fig. 50.

Haldde Observatory

One of Birkeland's greatest wishes was to establish the altitude of the aurora.

In 1899 he build two small observatories on the Haldde and Talvikstoppen mountains to solve this problems. Frequent storms, smoke inside, bad weather and a deadly avalanche in 1900 almost stopped the activities at the observatories. Also measuring the height was not successful.

Vi har herved den sorgelige pligt at bekjendtgjøre, at vor dygtige og af alle afholdte Kaptein

Adolf Richard Lange

forer af D/S Fortunatus omkom den 16de ds. ved ulykkestilfælde.

Begravelsen foregaar fra *direktørboligen i Kaafjord torsdag den 22de ds. kl. 3 eftm.*

Kaafjord den 19 marts 1900.

Allens kobbergruber
Fr. Schütz.

Roald Amundsen visited the observatory in 1902/3

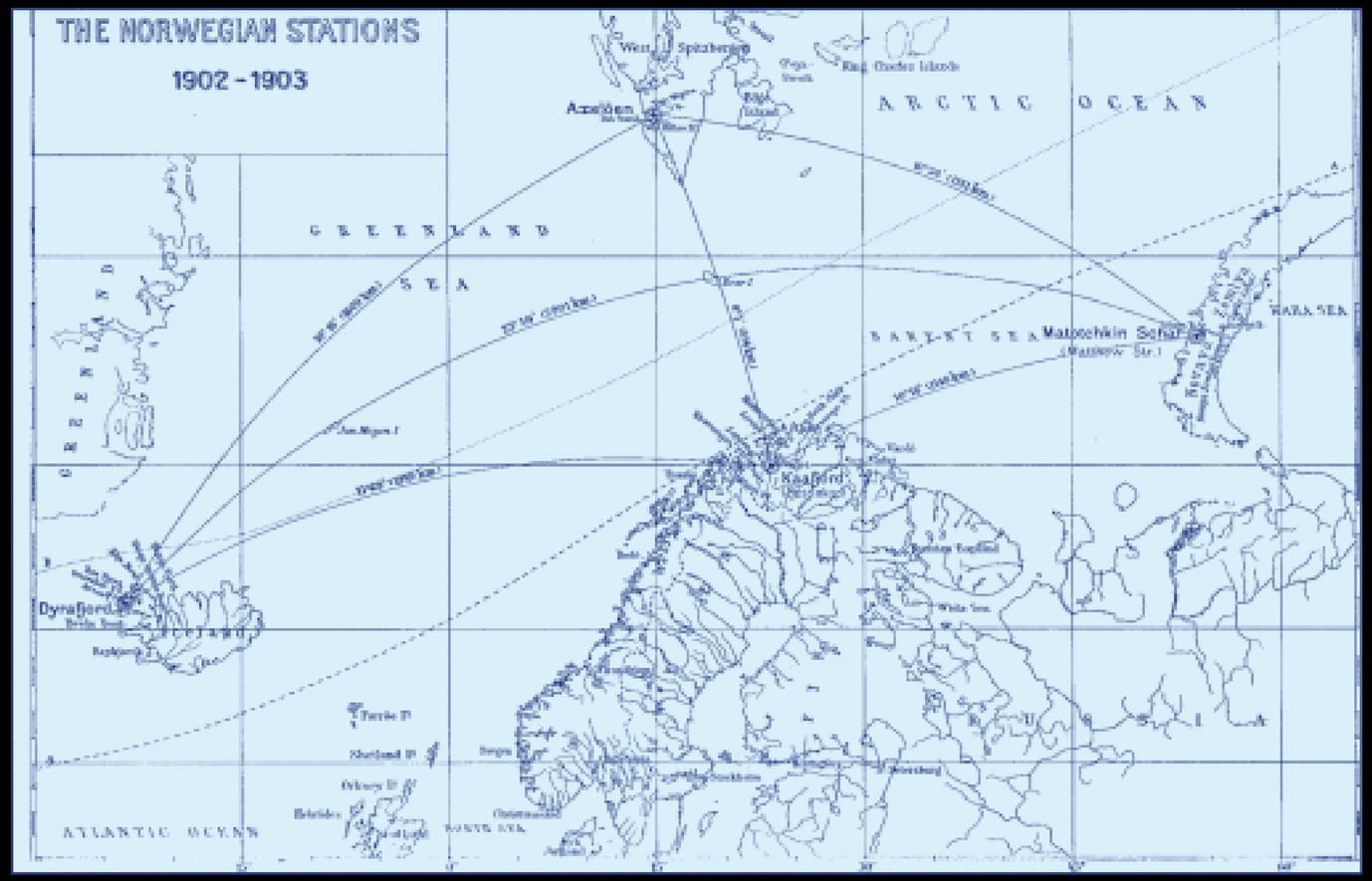
The Permanent Haldde Observatory 1912-1926

Birkeland was for some years busy with developing the fertilising technique and industry development, but in 1912 after an expedition to Egypt he managed to raise money for building a larger permanent observatory.

Here several families with children worked and lived all year.

The new and larger observatory

Setting up a magnetic observatory network



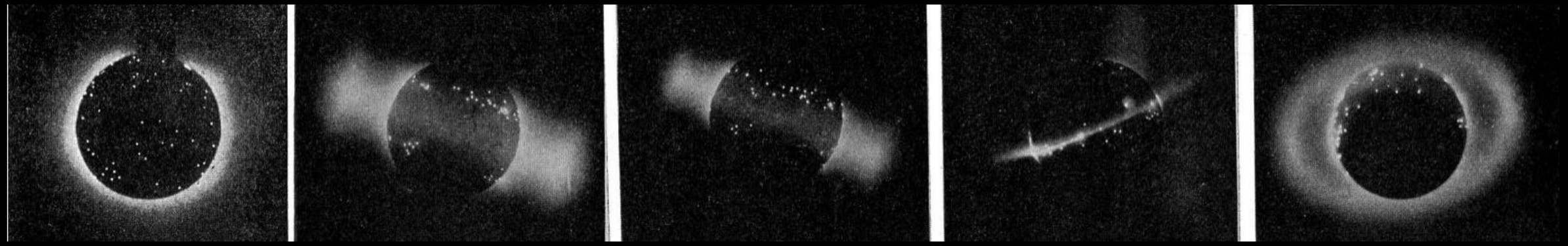
Birkeland - Solar Research

In 1908, Birkeland initiated a series of terrella experiments related to the Sun and its magnetic field.

He argued that sunspots were the footprints of intense electric discharges

Ho also took excellent pictures of the solar corona during an eclipse - and argued that the «radiation from the terrell strongly resemble the Sun’s corona»

And only when he added a strong magnetic field - the Sunspots converged closer to the equator.

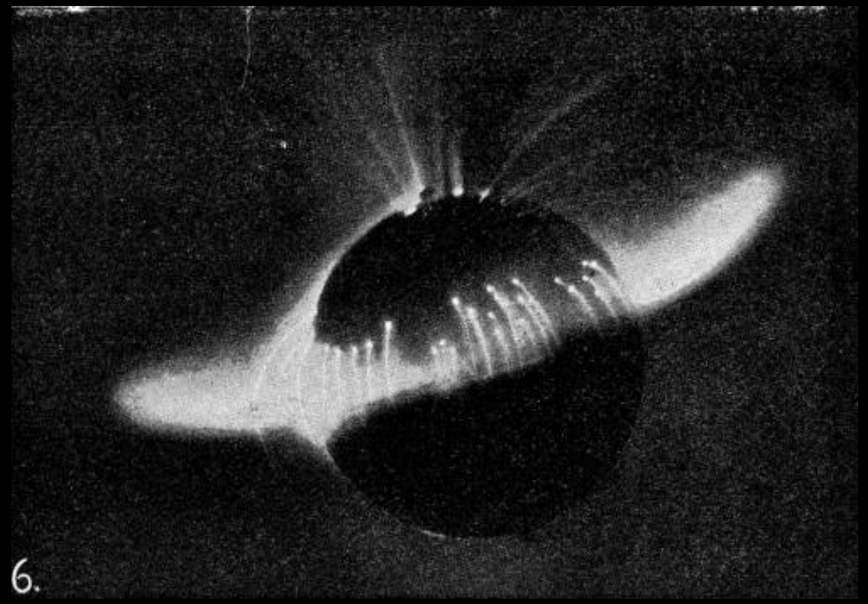


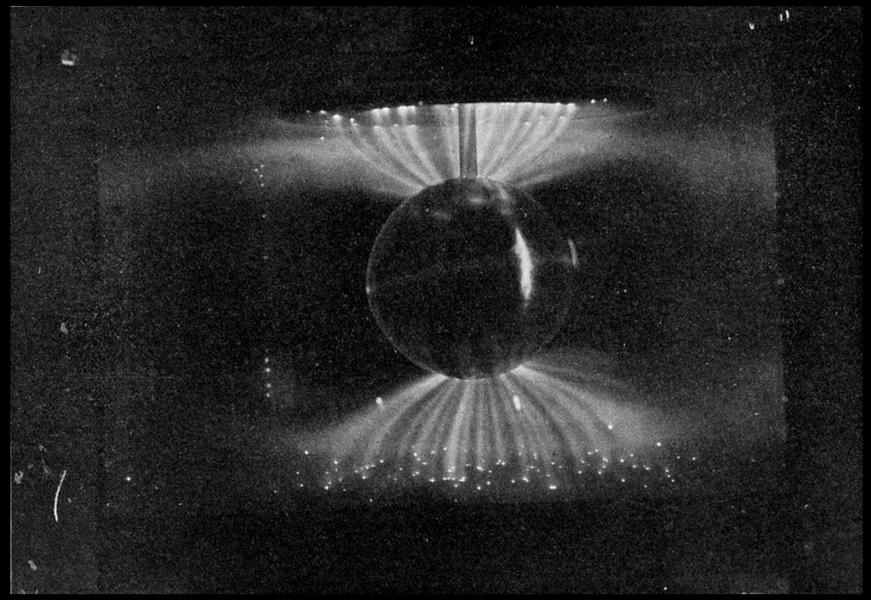
Birkelands Solar Research

He suggested that the 11-year sunspot cycle must be related to the Sun’s magnetic field, which derived from internal electric currents.

He understood that the dipole magnetic field of the Sun would inhibit the emission of charged particles at equatorial latitudes.

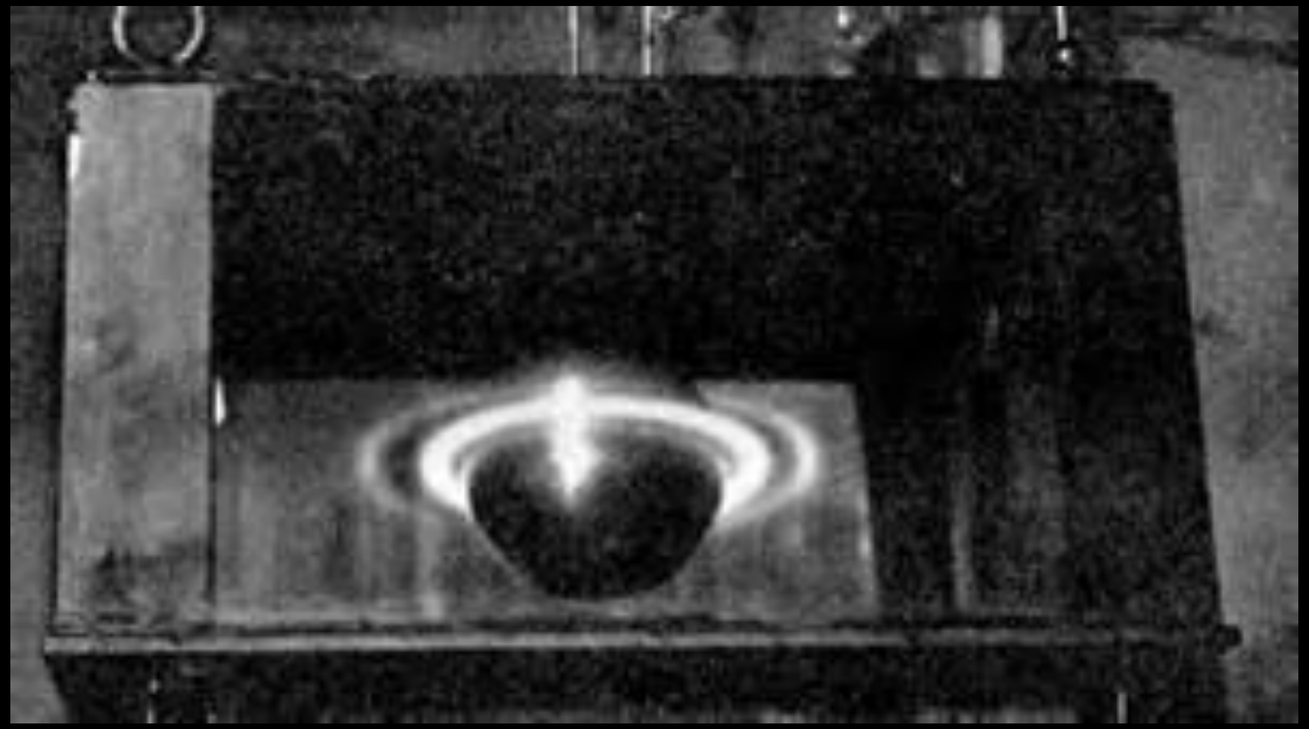
Charged particles flowing outward at polar latitudes would bend toward the equatorial plane

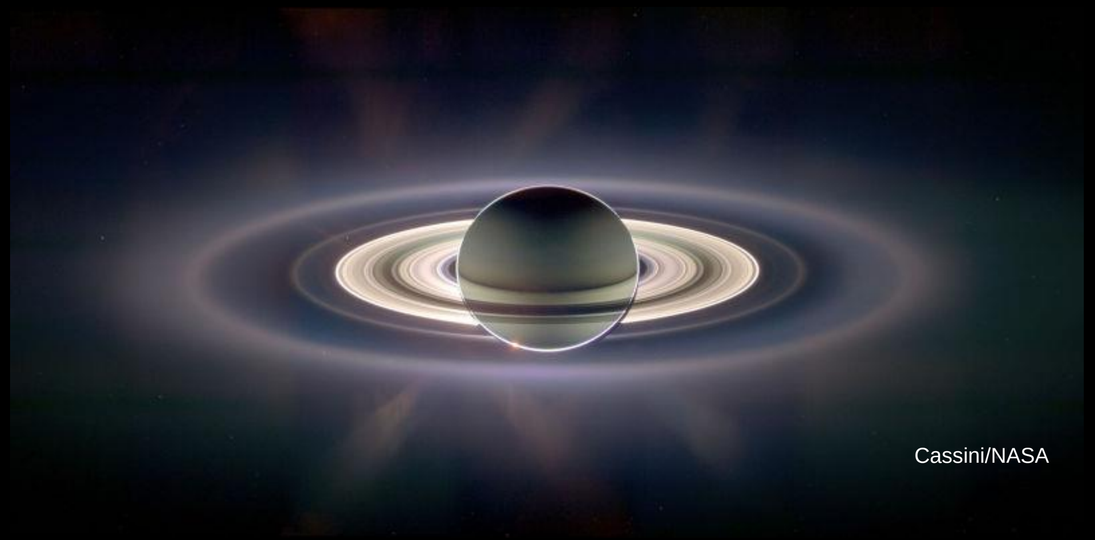




Birkeland studied the rings of Saturn

Birkeland was also very interested in the rings around Saturn. In 1910 i produced similar rings around his sphere in the vacuum chamber.

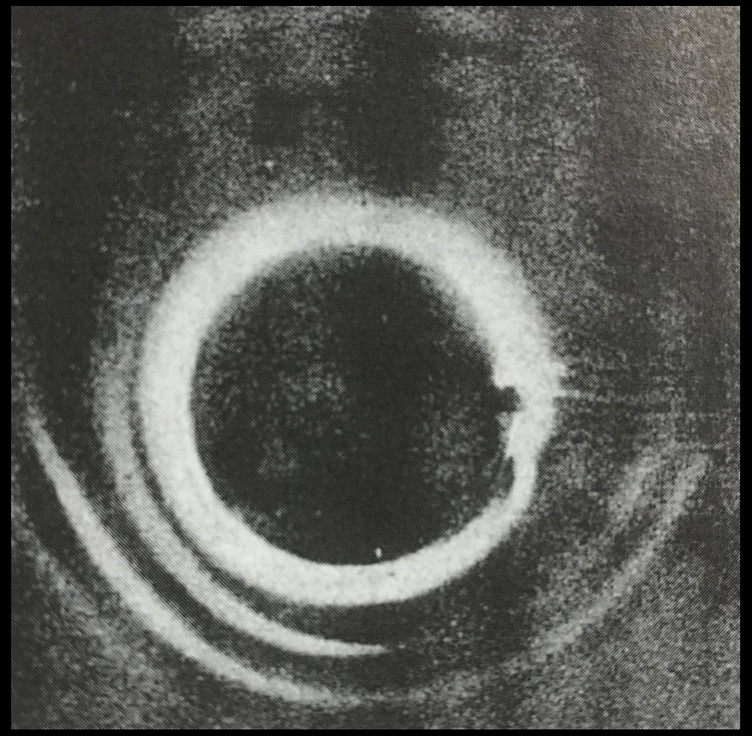




Cassini/NASA

Birkeland studied comet tails

Birkeland was also in comets and argued that charged particles could interact with evaporated matter from the comet. I tried to explain the different types of tails and also thought he fine structure in the tail of Halleys comet looked similar to the structures in the aurora.



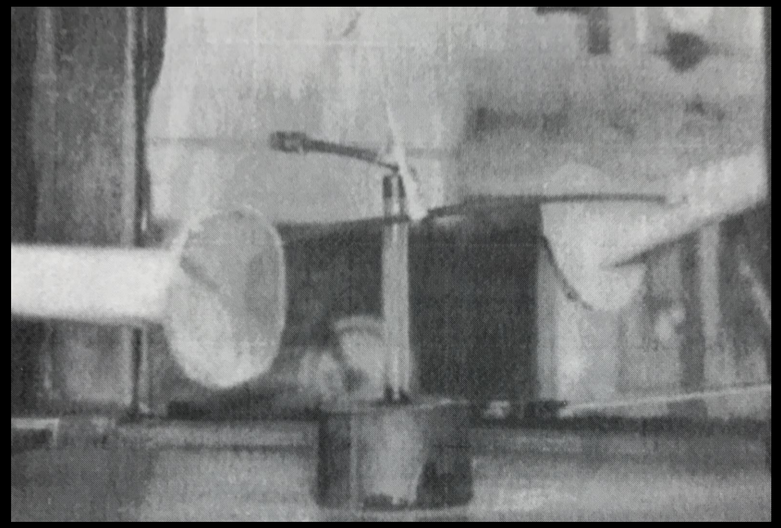
Birkeland - Rocket Propulsion

Birkeland and his assistants carried out several eksperiments that were never published

Olav Devik til a story where that tested spaceship propulsion. In French newspapers there were discussions about possibility to move through empty space - where there is nothing to push on.

Birkeland said: «No problem, but the propulsion will have to come from the reaction pressure from a catode».

He managed to demonstrate this in his vacuum-camber.



Birkeland studied the Zodiacal Light

Birkeland was very interested in the Zodiacal light - and argued that it was related to the particles from the Sun - and should be correlated with geomagnetic storms.

Expedition to Khedivial Observatory south of Cairo. After the first night - Birkeland asked the Governor of Omdurman to shut down all the light in the city.

He never found these rapid variations - and in 1914 he conclude that the Zodiacal light was ultraviolet wavelength - wanted to observe from a mountain (3000m).

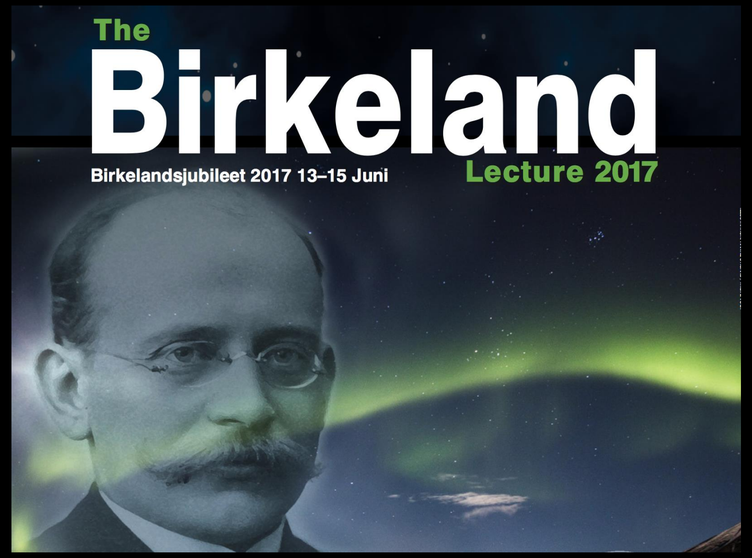
He then started testing with a photocell in one of the camera to detect weak light variations - and was a pioneer in this field.

Birkeland's sad fate.

When he was going back to Norway it was difficult to travel the normal route due to the First World War. Thus he took a detour via Tokyo to work with some colleagues and visit friends.

At that time he was mentally unstable and ended his life in a hotel room 15th June 1917.

Birkeland dies in Hotel Seiyoken, Tokyo

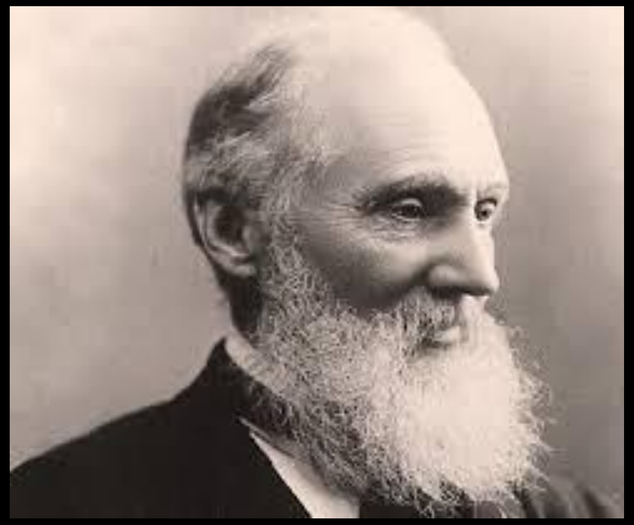


Birkeland - criticised by fellow scientists

Birkeland's theories about the northern lights and electrical currents in the atmosphere met great opposition among internationally renowned scholars such as Lord Kelvin and British scientist Sydney Chapman.

Lord Kelvin argued it was not possible that the Sun was responsible for the aurora - since space was «empty»

Chapman said that Birkeland expeditions to the arctic was unnecessary and his theory to way to «curious».



Lord Kelvin

Sydney Chapman

Satellites Confirms Birkeland Theories

In 1962 NASAs Mariner II spacecraft on its way to Venus measured the presence of an electrified gas with speed up to 300-700 km/s. This proved that «empty» space was not empty at all but filled with particles - the solar wind

In 1966 a U.S. Navy navigation satellite observed magnetic disturbances near polar regions. This lifted Birkeland's name again.

Electrical currents were detected by satellites in 1967 and 1973 just like Birkeland proposed

NASA Mariner II

Chapman vs Birkeland

At the 50 year anniversary after the death of Birkeland a large symposium was organised in Norway. An international committee decided to name the observed currents Birkeland Currents

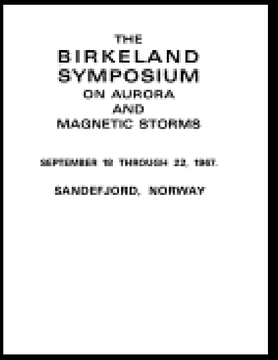
Even 50 years later (1967) Chapman stated this at a conference in Norway:

«Though Birkeland was certainly intensively interested in the aurora……it must be confessed that his direct observational contribution to auroral knowledge were slight»

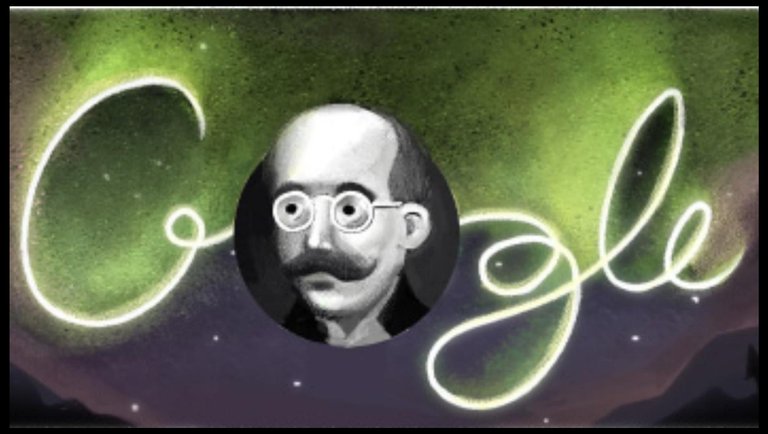
One young American scientist, Alex Dessler, questioned Chapman about Birkeland.

«I asked him wether Birkeland work had any influence on him at all»

«How could it? It was all wrong»



Just recently Birkeland got the honour he deserved



Science on a bill

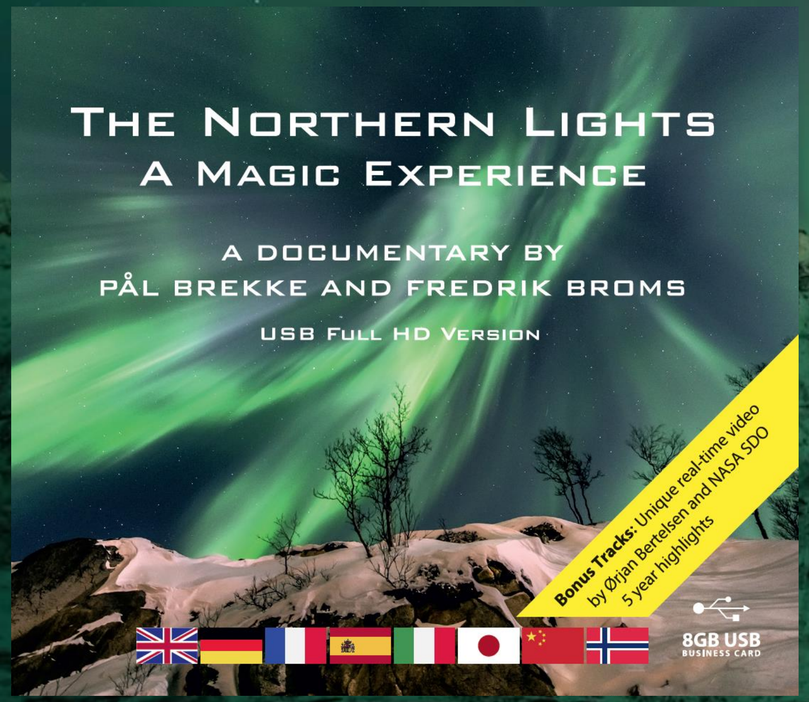
From the documentary «Northern Lights - a Magic Experience»

From the documentary «Northern Lights - a Magic Experience»

Birkeland- the first space scientist

What would Birkeland have done if he lived another 30 years?

What would Birkeland have been working on if he lived in our time?


THE NORTHERN LIGHTS
A MAGIC EXPERIENCE
A DOCUMENTARY BY
PÅL BREKKE AND FREDRIK BROMS
USB FULL HD VERSION
Bonus Tracks: Unique real-time video by Ørjan Bertelsen and NASA SDO
5 year highlights
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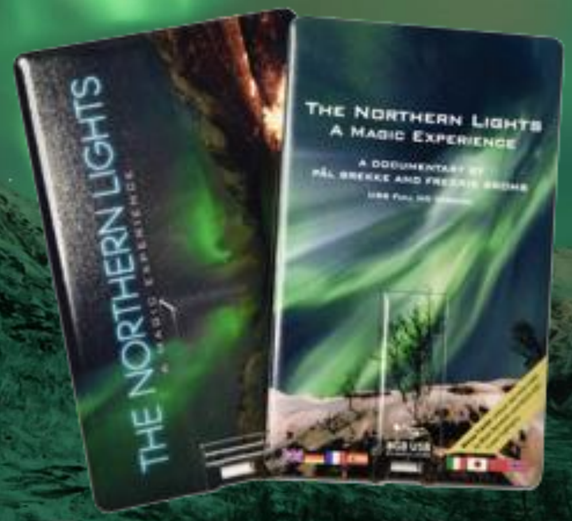
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