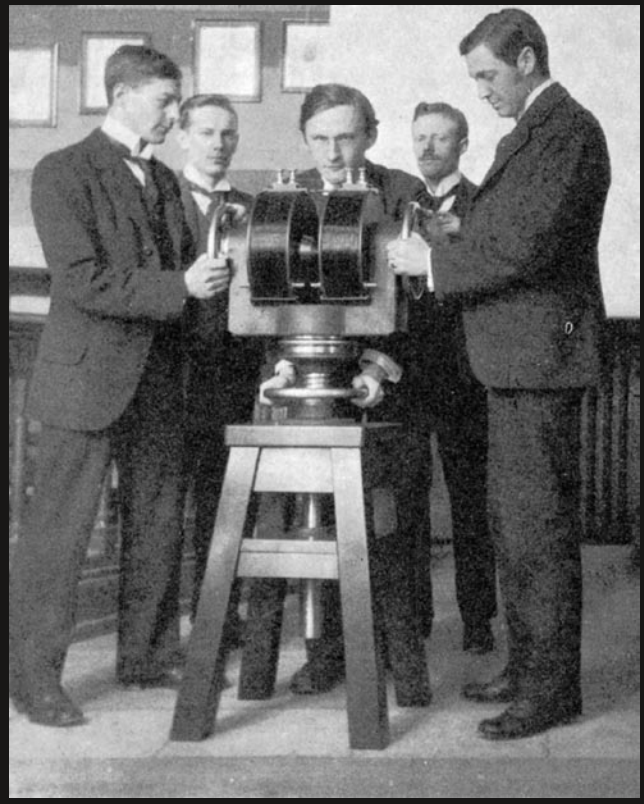


Successful students

Licentiates, doctoral students, and one lecturer, 1900 - 1930.

The dream of flying ...

Enoch Thulin was an important, and unconventional, student of Professor Janne Rydberg. He was born in 1881 in the small village of Simris, on the south coast of Sweden. Already as a child, he was fascinated by flying, and he began his studies at the Department of Physics in Lund in 1900.

As a boy I dreamed about flying. I built my first flying machine at school. My university studies were concerned with the theoretical and technical aspects of flying, and I was present at the very first flights in Europe. I have always been convinced that flying would revolutionize travel. The future of human culture may even rest on it.

Apart from anything else, flying is fun!

Quote from *Enoch Thulin: Forskare, flygare, företagare,* by Jan Wærnberg.

Enoch Thulin 1881 - 1919

... comes true

Enoch Thulin in a Thulin B, in the harbour at Mölle in 1917.

Janne Rydberg and Enoch Thulin worked together to develop a programme for a licentiate study in aerodynamics. This led to Thulin's, partially experimental, doctoral thesis, entitled, *On the Air Resistance of Thin Sheets at Varying Velocity*, which he defended in 1912, and which proved to be important in the understanding of aerodynamics. His examiner was Professor Rydberg himself, who awarded Thulin *a Pass with Distinction*.

The industrialist

In 1914, Enoch Thulin founded *Enoch Thulins Aeroplanfabrik*, which expanded rapidly, and at its peak had almost 800 employees. He employed several scientists from the Department of Physics.

The company manufactured engines and various models of aeroplanes designed by its engineers, and was the first aeroplane manufacturer in Sweden. Four different kinds of planes and three rotary engines were made at the factory.

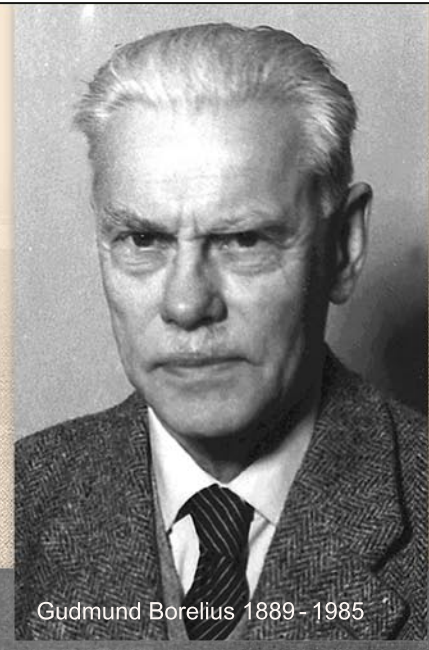
Following the death of Enoch Thulin in a flying accident in 1919, the production of aircraft at the company ceased.

Enoch Thulin's fatal crash on 14 May 1919, in one of the slipways at the Öresund Shipyard.

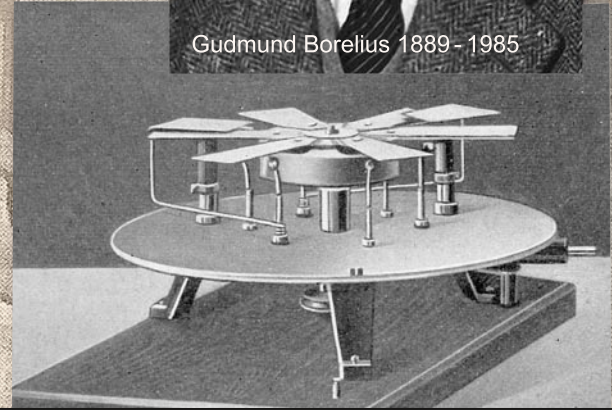
New physics

Gudmund Borelius started his studies in Lund with Professor Janne Rydberg as his supervisor. He presented his doctoral thesis, entitled *The Surface Potentials of Solutions in Contact with Insulators*, in 1915.

That same year, Professor Manne Siegbahn became head of the Department, and Borelius took over Siegbahn's position as teaching assistant.



Gudmund Borelius 1889 - 1985



The Swedish father of solid state physics

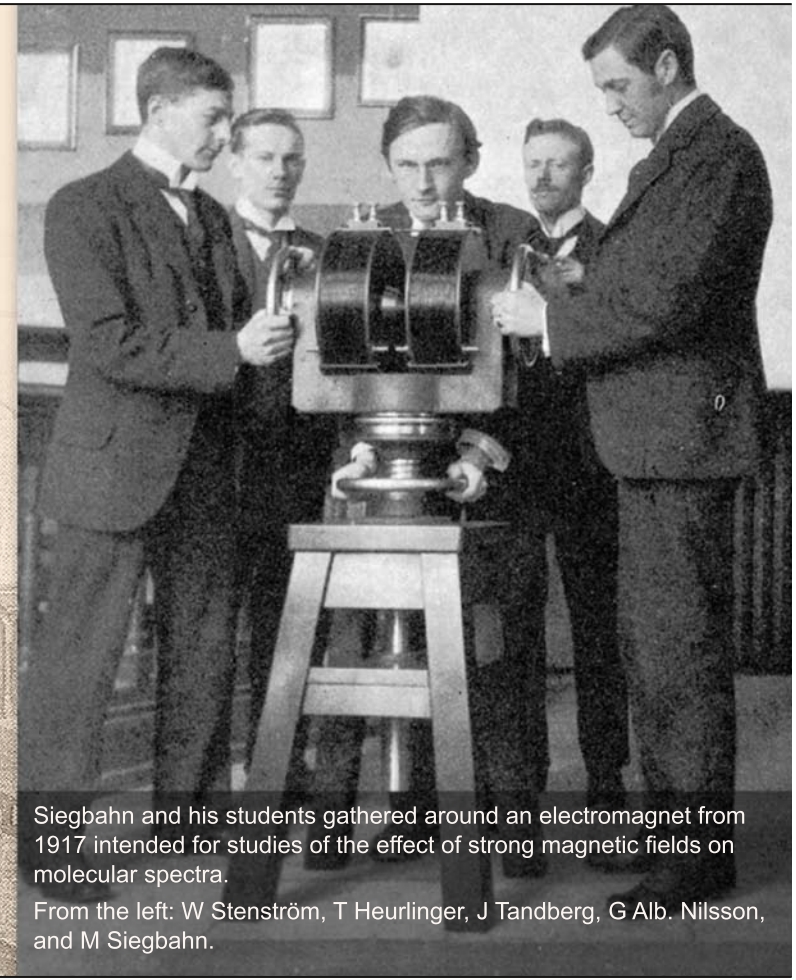
In 1922, Borelius became Professor of Physics at the Royal Institute of Technology in Stockholm. His field of research was solid state physics, and Borelius is considered to be the founder of the subject in Sweden. As professor at the Royal Institute of Technology he created the new subject of engineering physics in undergraduate teaching.

In his spare time, Borelius liked to draw, and at the age of 18 he illustrated the children's story *Three Red Apples*, which was published in a children's magazine in March 1907.

Talented students

Manne Siegbahn had an exceptional ability to attract talented students. He could thus delegate his teaching duties to his assistants, enabling him to concentrate on research and supervising doctoral students.

The influx of students was high at the beginning of the 1910s due to locally administered middle schools being given the same status as state-run grammar schools. This led to large groups of students for Siegbahn to enthuse, and who later had plenty of opportunities to carry out research when the intake of students fell.

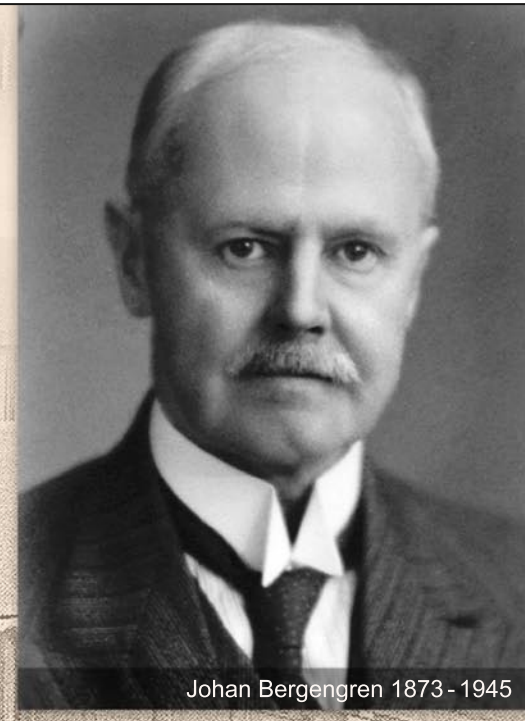


Siegbahn and his students gathered around an electromagnet from 1917 intended for studies of the effect of strong magnetic fields on molecular spectra.

From the left: W Stenström, T Heurlinger, J Tandberg, G Alb. Nilsson, and M Siegbahn.

Who was J Bergengren?

J Bergengren was a lecturer in mathematics and physics, but he had problems securing a permanent position. In order to broaden his qualifications, he decided to undertake further studies in physics at the age of 40, and applied for an experimental course. Upon completing the course, he was required to carry out a project, and he contacted Manne Siegbahn, who was thirteen years his junior. Siegbahn suggested that he study the absorption of X-rays by different forms of phosphorus and phosphoric acid.



Johan Bergengren 1873 - 1945

A historic project

Über die Röntgenabsorption des Phosphors.

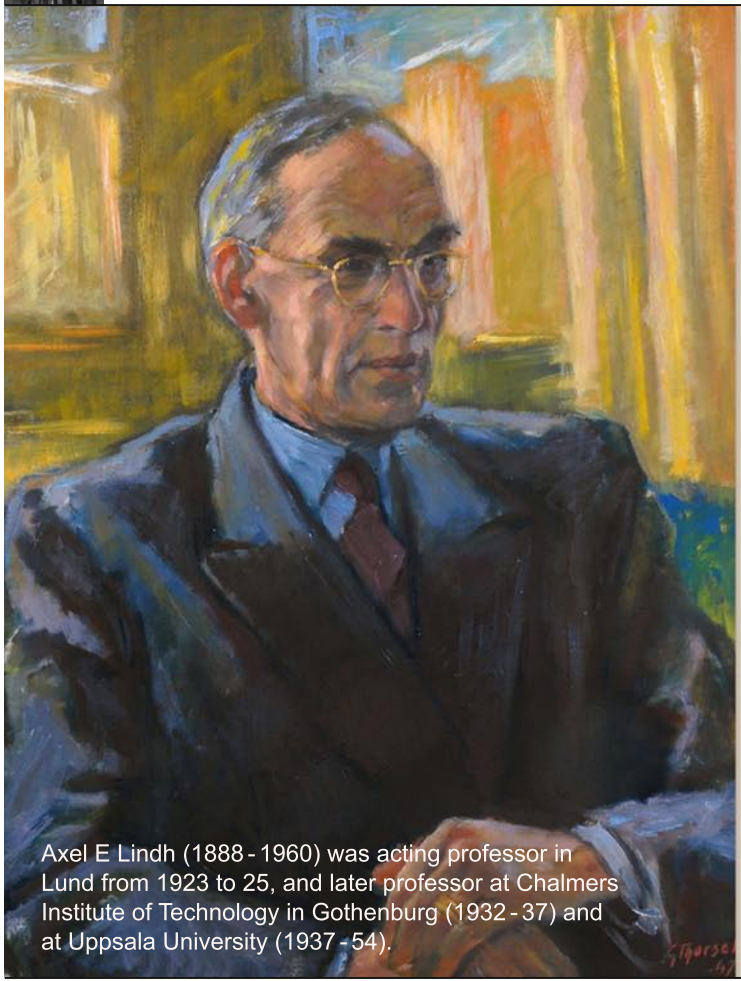
Von J. Bergengren.

Erste Mitteilung. (Eingegangen am 16. Oktober 1920.)

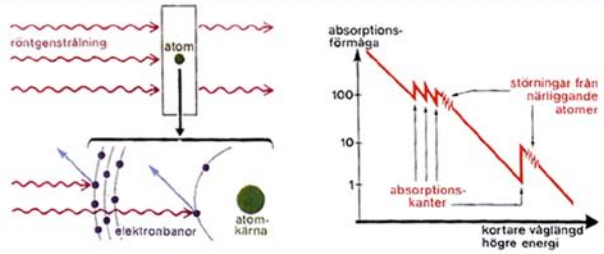
Bergengren's work was published in *Zeitschrift für Physik* in 1920.

Bergengren's project showed that it was possible to study the chemical binding of phosphorus atoms using X-rays. This was a historic result, which today still forms the basis of chemical analysis using X-rays. Although he had a doctorate in mathematics, he was a novice in experimental physics, but he became internationally known through this single physical study. Thanks to his new skills, he was appointed lecturer in mathematics and physics at Lund University.

X-ray absorption



Axel E Lindh (1888 - 1960) was acting professor in Lund from 1923 to 25, and later professor at Chalmers Institute of Technology in Gothenburg (1932 - 37) and at Uppsala University (1937 - 54).



A sketch of the priciple of X-ray absorption, and how it is affected by chemical binding.

Axel Lindh succeeded Borelius as a teaching assistant in 1920, after having presented his doctoral thesis on X-ray absorption by chlorine, sulphur and phosphorus. He was naturally interested in Bergengren's experiments on phosphorus, and was able to show that the position and structure of the absorption limit were dependent on the chemical binding of the atoms. This was a completely new finding, which was to be of fundamental importance in modern spectroscopy.

Many of the projects carried out at the MAX IV Laboratory today utilize this property to determine the structure of molecules.

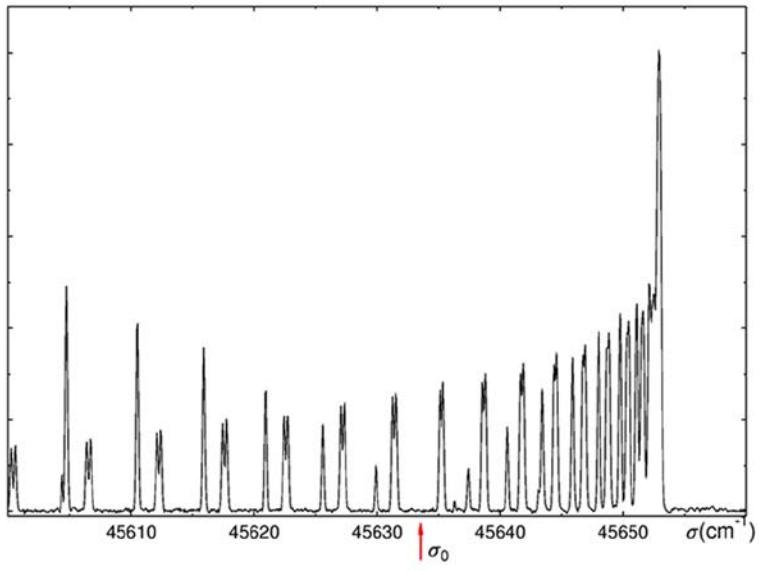
A young talent

Torsten Heurlinger was born in Halmstad, some 130 km away, but he attended upper secondary school in Lund. It was clear early on that he had a particular talent for science and mathematics.

After obtaining his degree in physics, mathematics, mechanics and astronomy, he studied under Professor Walfrid Ekman, dedicating his time to mathematical physics. His interest was soon directed towards the band spectra of molecules whose interpretation, in contrast to the line spectra of atoms, was still shrouded in mystery.

Torsten Heurlinger 1893 - 1927

Band spectra



This modern spectrum has significantly better resolution than the photographic spectra analysed by Heurlinger.

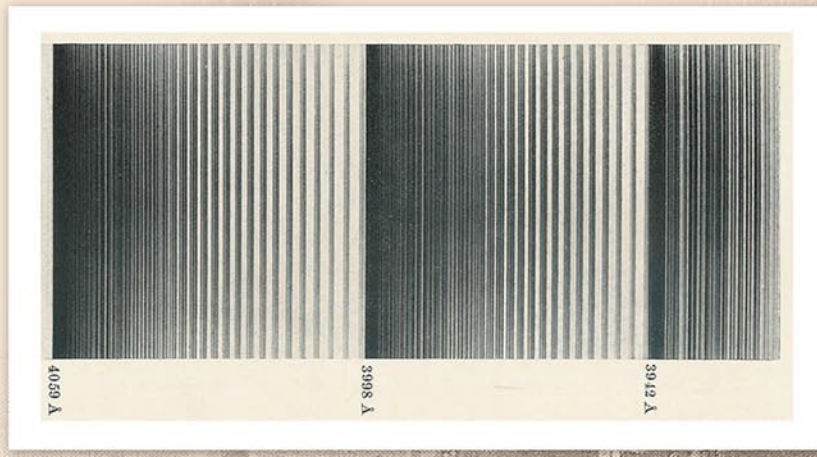
Heurlinger's studies of band spectra were carried out in close collaboration with Siegbahn's research group, especially Erik Hulthén. He presented the results of these studies in his doctoral thesis, *Studies on the Structure of Band Spectra*, in 1918, aged only 25.

It had previously been assumed that the series of lines in a band started at the edge of the band, but Heurlinger showed that the series started in the complicated band structure (arrow).

A curtailed career

Heurlinger developed a theory based on the rotation and vibration of molecules, and with the aid of the principles used by Niels Bohr in his atomic model, he was able to explain how the bands were formed. Heurlingers work form the basis of modern molecular spectroscopy.

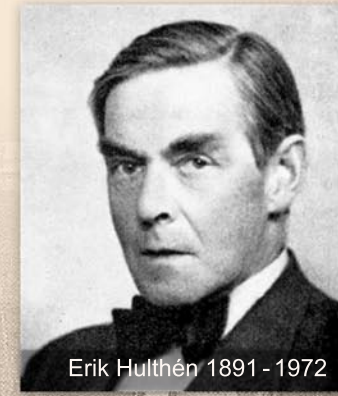
Unfortunately, Heurlinger did not have the opportunity to develop his theories as he was forced to give up his research in 1920 due to serious illness.



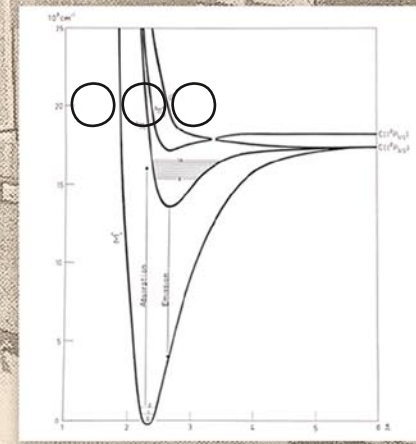
Molecular spectroscopy

Erik Hulthén had worked together with Torsten Heurlinger in the experiments on molecular spectra. When Heurlinger was forced to leave the department due to illness, Hulthén continued the work.

Hulthén obtained his doctorate in 1923, his thesis entitled *On the Combinatorial Relations of Band Spectra*. Six years later, in 1929, Hulthén was appointed Professor of Physics at what is now Stockholm University.

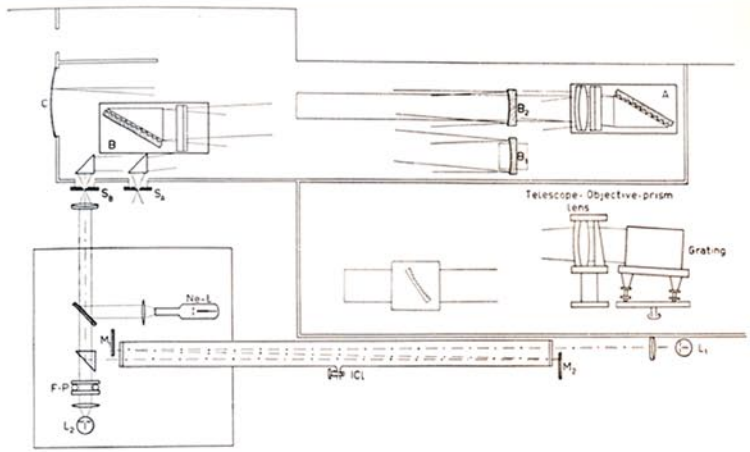


Erik Hulthén 1891 - 1972



Absorption and emission of an iodine chloride molecule.

Spectroscopic instruments



S_A	Entrance-slit for the lens equipment
A	Immersion-grating in autocollimation
S_B	Entrance-slit for the concave mirror equipment
B	Immersion-grating in the Pfund-mounting
B_1	Collimating mirror
B_2	Focussing mirror
C	Photographic plate holder
L_1	Zirconium-oxide lamp
M_1, M_2	Plane mirrors for multipole passages of light through the absorption cell *ICl*
L_2	Sylvania lamp
F-P	Fabry-Perot etalon

As the newly appointed Professor of Physics, Hulthén lost no time in appointing a professor of mechanics. He wanted to modernize the subject of physics at the University and decided that this theoretical position should be held by someone who had carried out research in atomic theory. The choice fell on Oskar Klein, previously a student of Svante Arrhenius.

Hulthén established experimental molecular physics at Stockholm University, where he carried out extensive studies of molecular spectra, and developed optical and spectroscopic instruments.

Niels Bohr's assistant

$$\frac{1}{c^2}\frac{\partial^2}{\partial t^2}\psi - \nabla^2\psi + \frac{m^2c^2}{\hbar^2}\psi = 0.$$

The Klein-Gordon equation

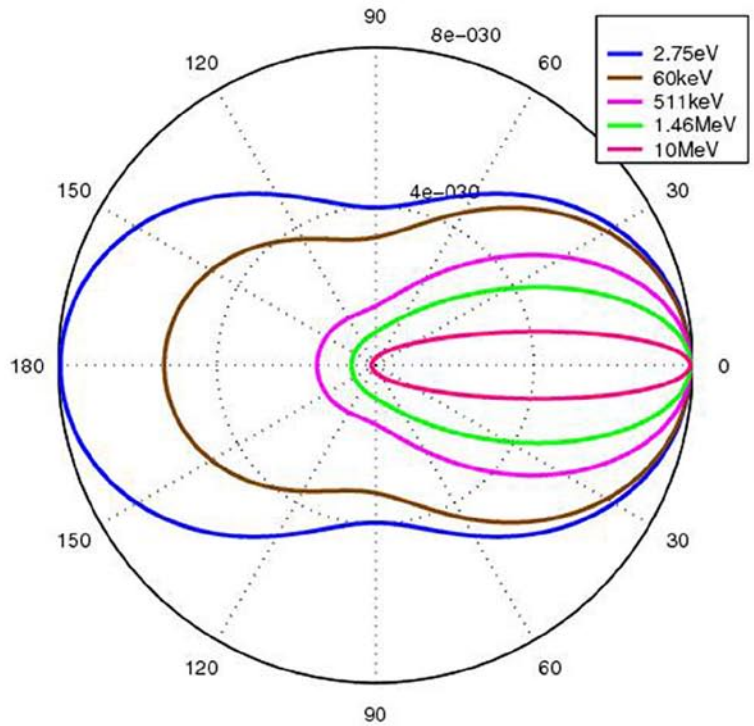
or in another system of units

$$-\partial_t^2\psi + \nabla^2\psi = m^2\psi$$

Oskar Klein 1894 - 1977

Oskar Klein was interested in modern quantum physics already as a PhD student. At the time of the Siegbahn-Sommerfeld conference in 1919 he was Niels Bohr's assistant, and in the spring of 1923, after obtaining his doctorate, he took up a position in Lund. At this time, Klein presented Niels Bohr's theory of the atom in *Kosmos*, the yearbook of the Swedish Physical Society. By 1927, when the principle of complementarity was formulated, he had become Niels Bohr's closest collaborator.

Klein the visionary



The Klein-Nishina distribution of photon scattering angle at different energies.

In 1930 Oskar Klein was appointed Professor of Physics at what is now Stockholm University, but his most famous work was carried out during his time in Lund (1923 - 1928), namely the five-dimensional unified field theory, which can be said to be a precursor to string theory, the Klein–Gordon equation, which is a further development of the Schrödinger equation including corrections for relativistic effects, the Klein–Nishina formula, and Klein's paradox.

Klein's paradox states that when electrons meet an electric potential in vacuum, the number of electrons reflected by the potential is greater than the number impinging on it when the potential exceeds a certain value.