

# *Keeping things open*

*Tomas Bohr*

*Technical University of Denmark*



*Bolatta Silis-Høegh*

How could Niels Bohr attract such a creative environment?  
*What does it take?*



Niels Bohr with some of his “disciples” in the 1930’ies :

Courage / ambition:

Take up the most important problems, even though you might not have all the tools you need

# Speech at the Nobel banquet (1922)

*When the great experimental discoveries around the turn of the century, in which investigators from many countries took such a prominent part, gave us an unsuspected insight into the constitution of atoms, we owe this above all to the great researchers of the English school, Sir Joseph Thomson and Sir Ernest Rutherford, who have inscribed their names in the history of science as shining examples of how imagination and acute insight are capable of looking through the multiplicity of experiences and laying bare to our eyes the simplicity of Nature. On the other hand, abstract thought, which has always been one of mankind's most powerful aids in lifting the veil that conceals the laws of nature to the immediate observer, has been of decisive significance for applying the insight gained into atomic structure to explain the properties of the elements directly accessible to our senses. Also in this work, men of many nations have made important contributions; but it was the great German scientists, Planck and Einstein, who, through their abstract and systematic studies, first taught us that the laws holding for the motion of atomic particles, which govern the properties of the elements, are of an essentially different nature than the laws by which science hitherto had attempted to order our observations of the phenomena of nature. That is has been my undeserved good fortune to be a connecting link at a stage in this development is only one piece of evidence among many of the fruitfulness, in the world of science, of the closest possible intercommunication of research work developing under different human conditions.*

Between Germany and  
England

*On the way back  
from England  
- with Margrethe  
waiting at home*

QuickTime® and a  
decompressor  
are needed to see this picture.

# Explain the structure of the atom! - and molecules...

The first part of the “Trilogy”  
from 1913. All in all 71 pages in  
*Philosophical Magazine*

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Start with the simplest, and proceed by introducing strange “postulates”.

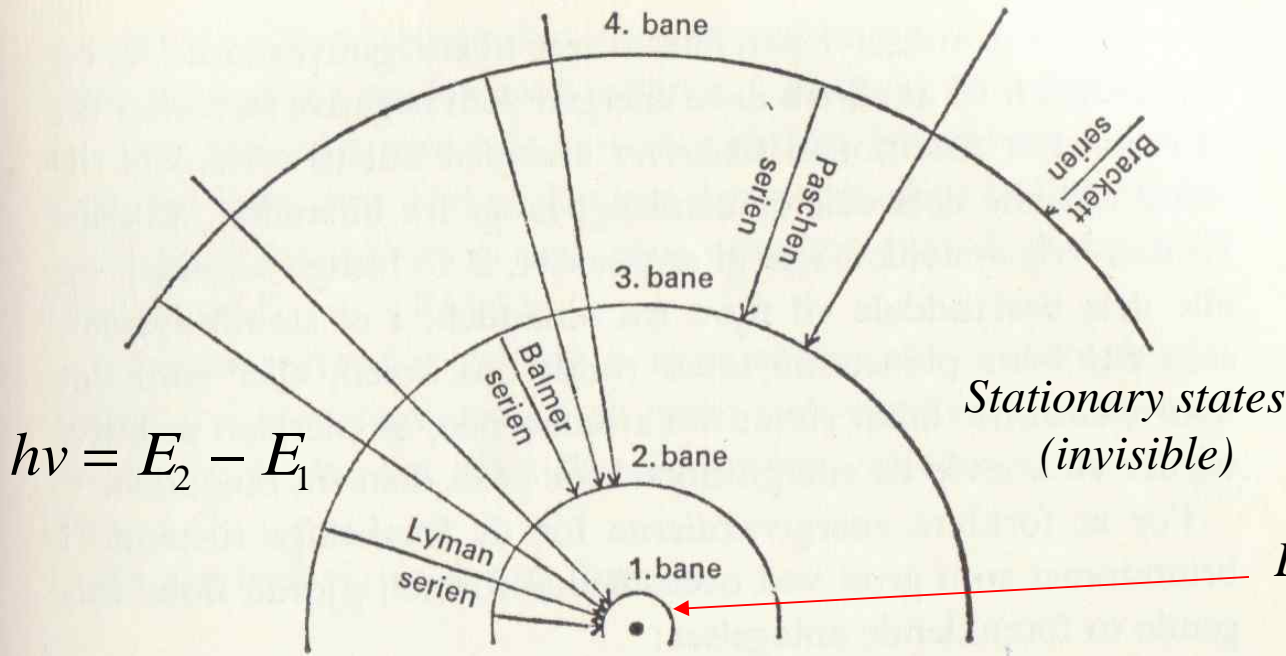


Fig. 12. Bohrs originale model af brintatomet. Lyman serien er i det ultraviolette, Balmer serien i den synlige del af spektrret, Paschen og Brackett serierne er i det infrarøde.

$$\text{Bohr radius } r_0 = \frac{\eta^2}{\mu \epsilon^2}$$

For the first time:  
a relation between  
light and matter !

$$\text{Bohr (1913): } \nu = K \left( \frac{1}{v_1^2} - \frac{1}{v_2^2} \right) \Rightarrow K = \frac{2\pi^2 \epsilon^4 \mu}{\eta^3}$$

$\mu, \epsilon$ :  $\mu$  ασχηρογε οφελεχρον,  $\eta$ . Πανακωχονσωντ

March 20, 1913.

Dear Dr. Bohr,

I have received your paper safely and read it with great interest, but I want to look over it again carefully when I have more leisure. Your ideas as to the mode of origin of spectrum and hydrogen are very ingenious and seem to work out well; but the mixture of Planck's ideas with the old mechanics make it very difficult

to form a physical idea of what is the basis of it. There appears to me one grave difficulty in your hypothesis, which I have no doubt you fully realise, namely, how does an electron decide what frequency it is going to vibrate at when it passes from one stationary state to the other? It seems to me that you would have to assume that the electron knows beforehand where it is going to stop.

There is one criticism of minor character which I would make in the arrangement of the paper. I think in your endeavour to be clear you have a tendency to make your papers much too long, and a tendency to repeat your statements in different parts of the paper. I think that your paper really ought to be cut down, and I think this could be done without sacrificing anything to clearness. I do not know if you appreciate the fact that long papers have a way of frightening readers, who feel that they have not time to dip into them.

I will go over your paper very carefully and let you know what I think about the details. I shall be quite pleased to send it to the *Phil. Mag.* but I would be happier if its volume could be cut down to a fair amount. In any case I will make any corrections in English that are necessary.

I shall be very pleased to see your later papers, but please take to heart my advice, and try to make them as brief as possible consistent with clearness. I am glad to hear that you are coming over to England later and we shall be very glad to see you when you come to Manchester.

By the way, I was much interested in your speculations in regard to Fowler's spectrum. I mentioned the matter to Evans here, who told me that he was much interested in it, and I think it quite possible that he may try some experiments on the matter when he comes back next term. General work goes well, but I am held up momentarily by finding that the mass of the  $\alpha$ -particle comes out rather bigger than it ought to be. If correct it is such an important conclusion that I cannot publish it until I am certain of my accuracy at every point. The experiments take a good deal of time and have to be done with great accuracy.

Yours very sincerely,

E. RUTHERFORD.

P.S. I suppose you have no objection to my using my judgment to cut out any matter I may consider unnecessary in your paper? Please reply.



*Be ready to abandon*

*Orbits and Causality*

Stamina / intensity / raw power

# Enormous output

12 volumes of "Collected  
works"

Papers

Letters

Applications

*7 lectures in 10 days !*



Werner Heisenberg

*Bohr-Festspiele*  
in Göttingen  
summer 1922



Wolfgang Pauli

Schrödinger's visit in 1926:  
smooth electron waves or  
quantum jumps?

*... For though Bohr was an unusually considerate and obliging person, he was able in such a discussion, which concerned epistemological problems, which he considered to be of vital importance, to insist fanatically and with almost terrifying relentlessness on complete clarity in all arguments.*

Heisenberg (1963)



# Memories from Gammelholms Latin- og Realskole

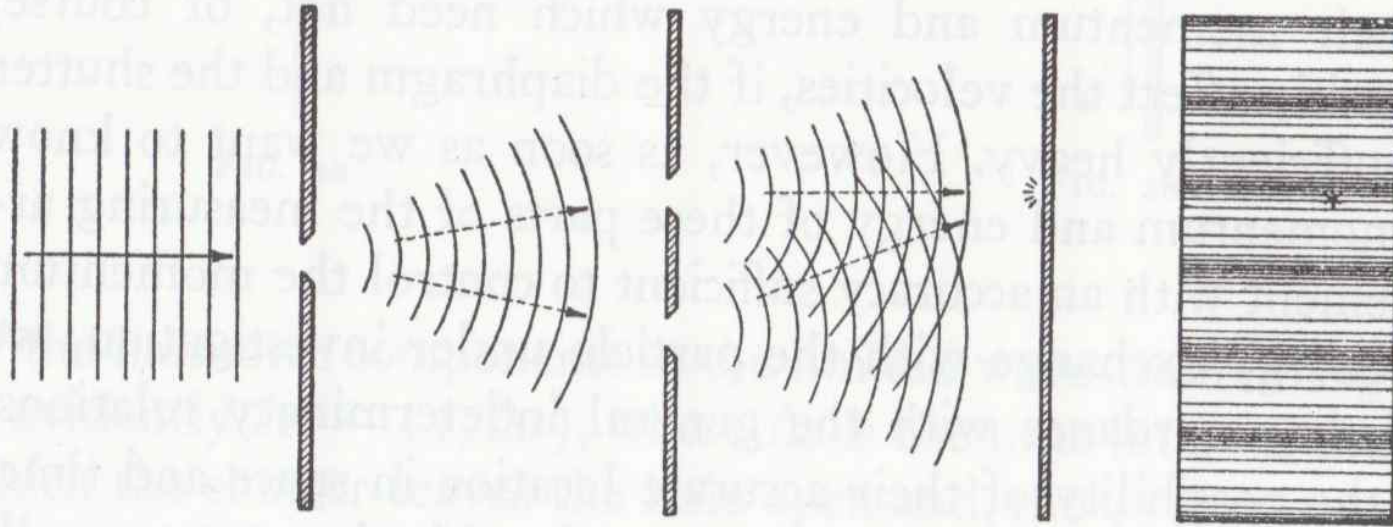
Aage Berleme (1952)

It sounds like a paradox, but during all the years when Niels was a *small* boy, I actually remember him as a very *big* boy. He was large of body, rather roughly hewn and strong like a bear, while I was the youngest in the class and a skinny little kid. In those years, Niels was certainly not afraid of using his strength and was always involved, when there was a fight. Fights were, then, very common during the school-breaks, and even took place outside the School at Skt. Annæ square.

I don't know what we were fighting about at that time, but Niels acquired a reputation as a strong boy, one can say a violent boy, since, during his entire childhood, he had problems judging the range of his actions, and probably many of the "bloody noses" he handed out were not intentional. He has beaten me numerous times.

*Ability to think concretely*

One of Einstein's favourite gedanken-experiments:



Young's “double slit experiment” with electrons or with single photons. Quantum mechanics predicts that one cannot determine which of the two slits the particle chooses *and* see the interference pattern. Einstein didn't believe this: in principle the trajectory of the particle can be measured e.g., from recoil.



Niels Bohr: you must build the experiment for a specific measurement.  
First example: Bolting the diaphragms to the table allows phase coherence but prevents measurement of path taken

Der kræves QuickTime<sup>a</sup> og  
et -komprimeringsværktøj,  
for at man kan se dette billede.

From: *Discussions with Einstein on Epistemological Problems in Atomic  
Physics.* (1949)

Niels Bohr's second example:  
allowing the diaphragm to move  
allows the observation of a  
recoil and thus the path of the  
particle, but destroys phase  
coherence.

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decompressor  
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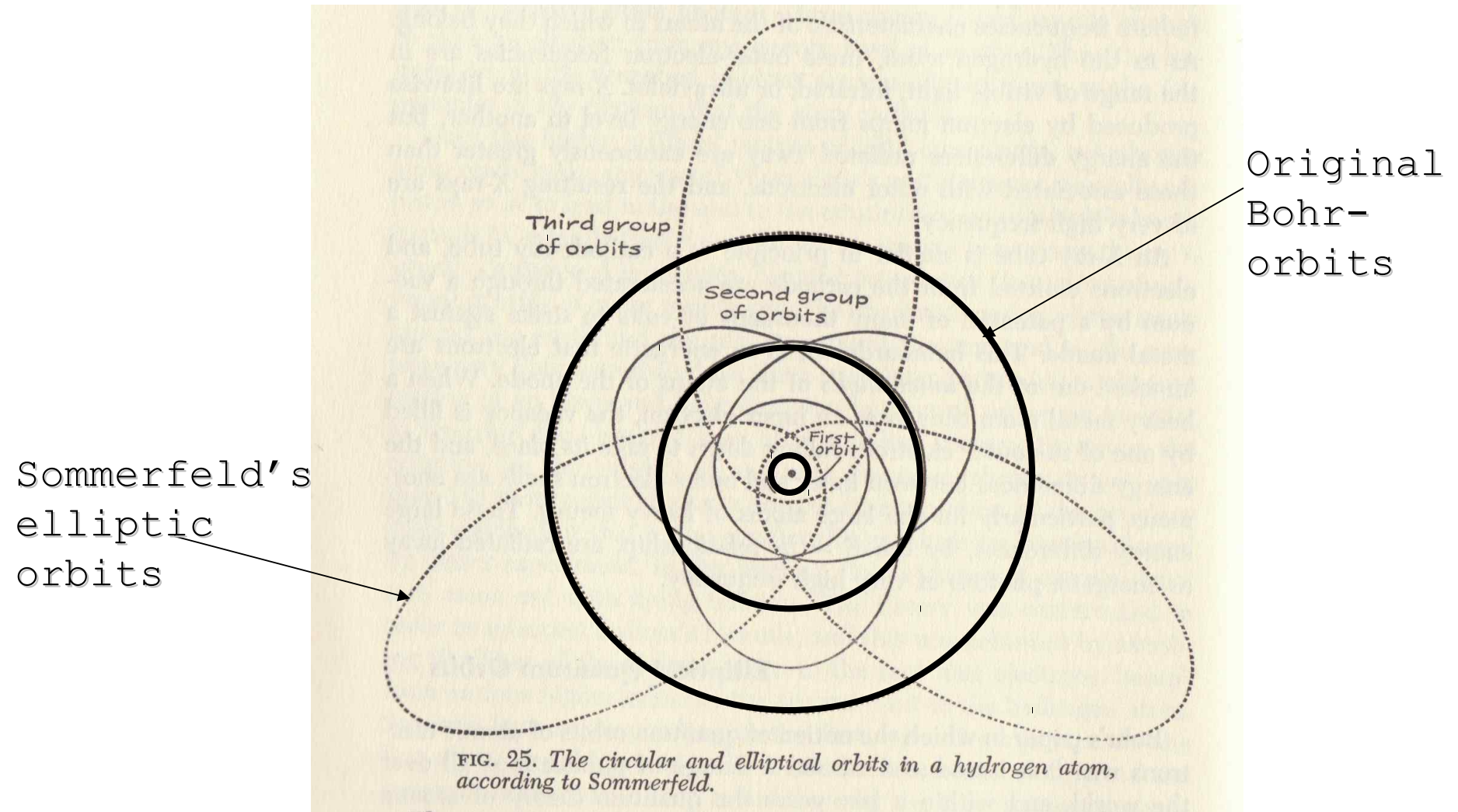
From: *Discussions with Einstein on  
Epistemological Problems in Atomic  
Physics.* (1949)

Joy of being wrong

From time to time there was alarming news of some experimental result which appeared to contradict what we knew. Such a contradiction was an enemy immediately to be attacked, against which Niels Bohr turned the full power of his mind. Sometimes it turned out that the experiment had simply been wrong, and everybody was relieved. But on other occasions Niels Bohr would tell us with even greater delight that it was he who had made a mistake, that the inconsistency disappeared when one had found the right way to think about it. He never hesitated for one moment to admit that he had been in error. To him it merely meant that he now understood things better, and what could have made him happier?

*O. R. Frisch: What Little I remember (1979)*

# Sommerfeld 1916



Sommerfeld's elliptic orbits drawn by Gamow.

• • • • •

The intention of writing all this is only to tell you how exceedingly glad I was to receive your papers before my paper was published. I decided at once to postpone the publication and to consider it all again in view of all, for which your papers have opened my eyes.

• • • • •

I do not know how to express, how I wish that the present terribly sad state of the world may change soon. I am hoping very much to meet you soon again and send the kindest regards to you and all the other physicists in your laboratory not only from myself but from all here.

Yours very sincerely

N. Bohr.

PORTLAND  
UNIVERSITY  
19, 1910.  
I do not  
the study  
this letter  
of course  
as the  
at any  
and the  
I am glad  
measure it

Close association  
to family and others

The whole family





From the left:

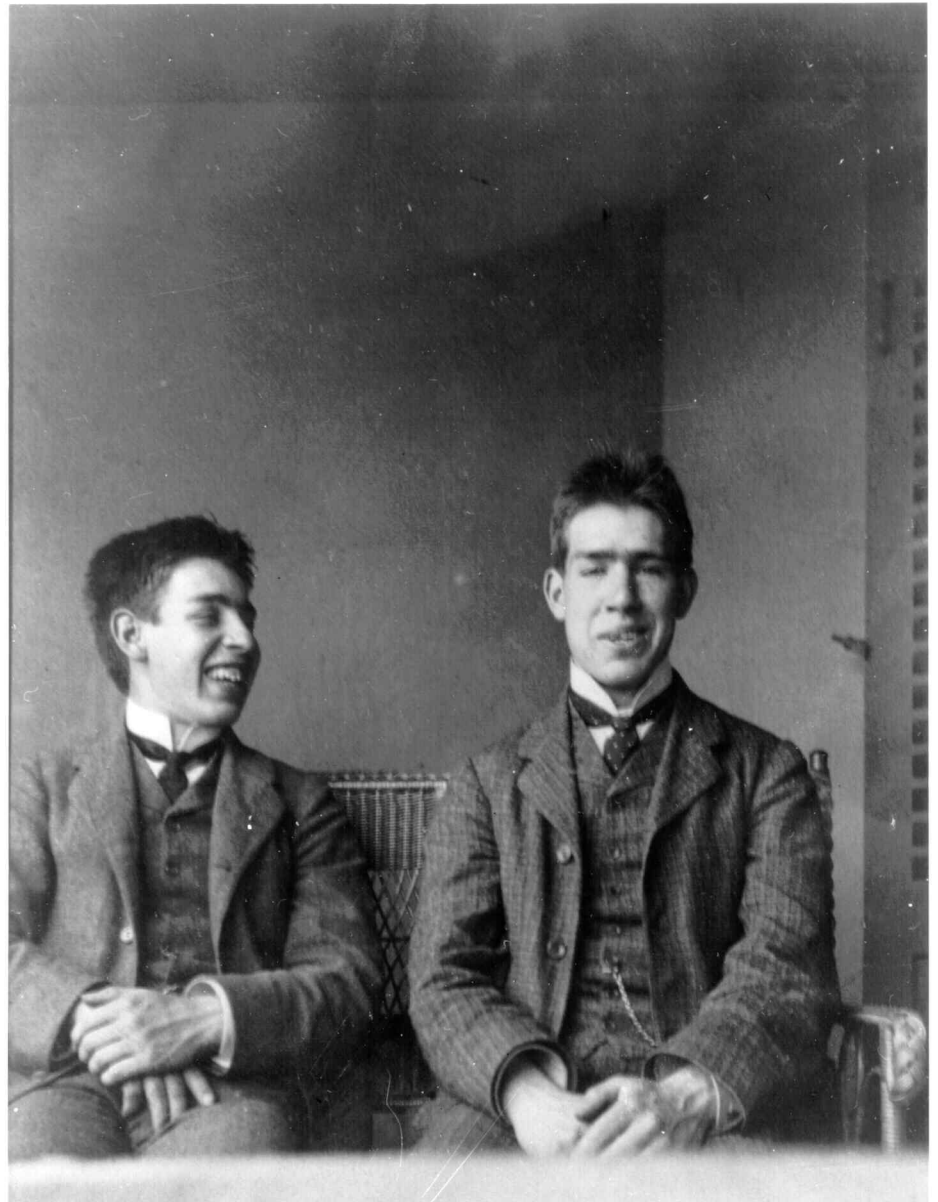
*Jenny* (sister), *Harald*  
(brother), *Ellen* (mother),  
*Niels*



*I think it symbolizes a certain aspect of our relationship with one another. My impudence and your being a little embarrassed on my behalf, but also - as it was I who said it, and as we always have been a little fond of each other - then you think nevertheless in all your niceness that it was nevertheless quite amusing to have such an impudent little brother.*

Letter from Harald to Niels (in Cambridge) 4.10.11

Translated by Finn Aaserud



Niels and Harald in  
1902

Margrethe Nørlund  
around 1909



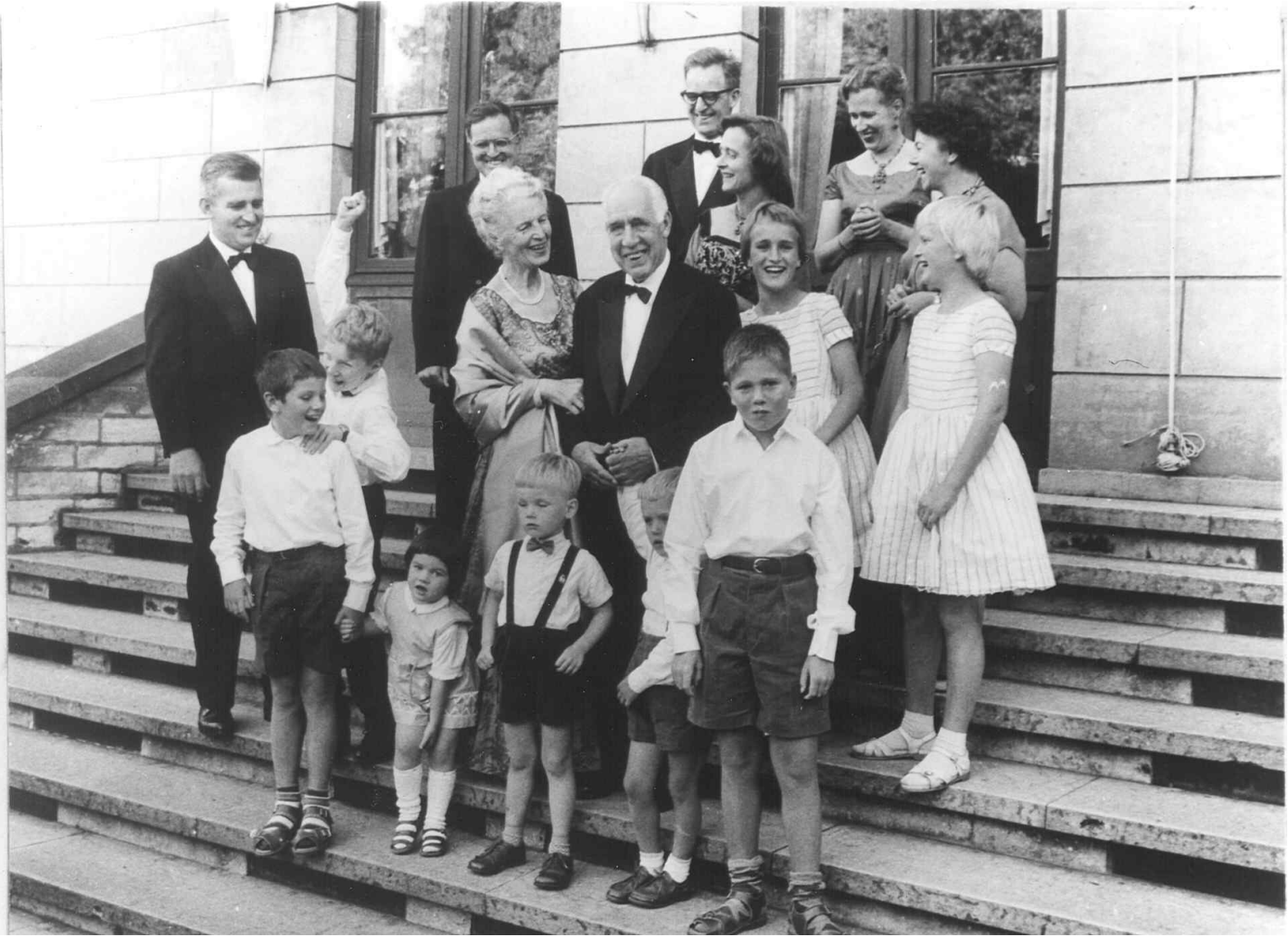
*The father with his sons*





Niels Bohr with his first grandchild Anne in 1947

# The Grandfather with some of the family



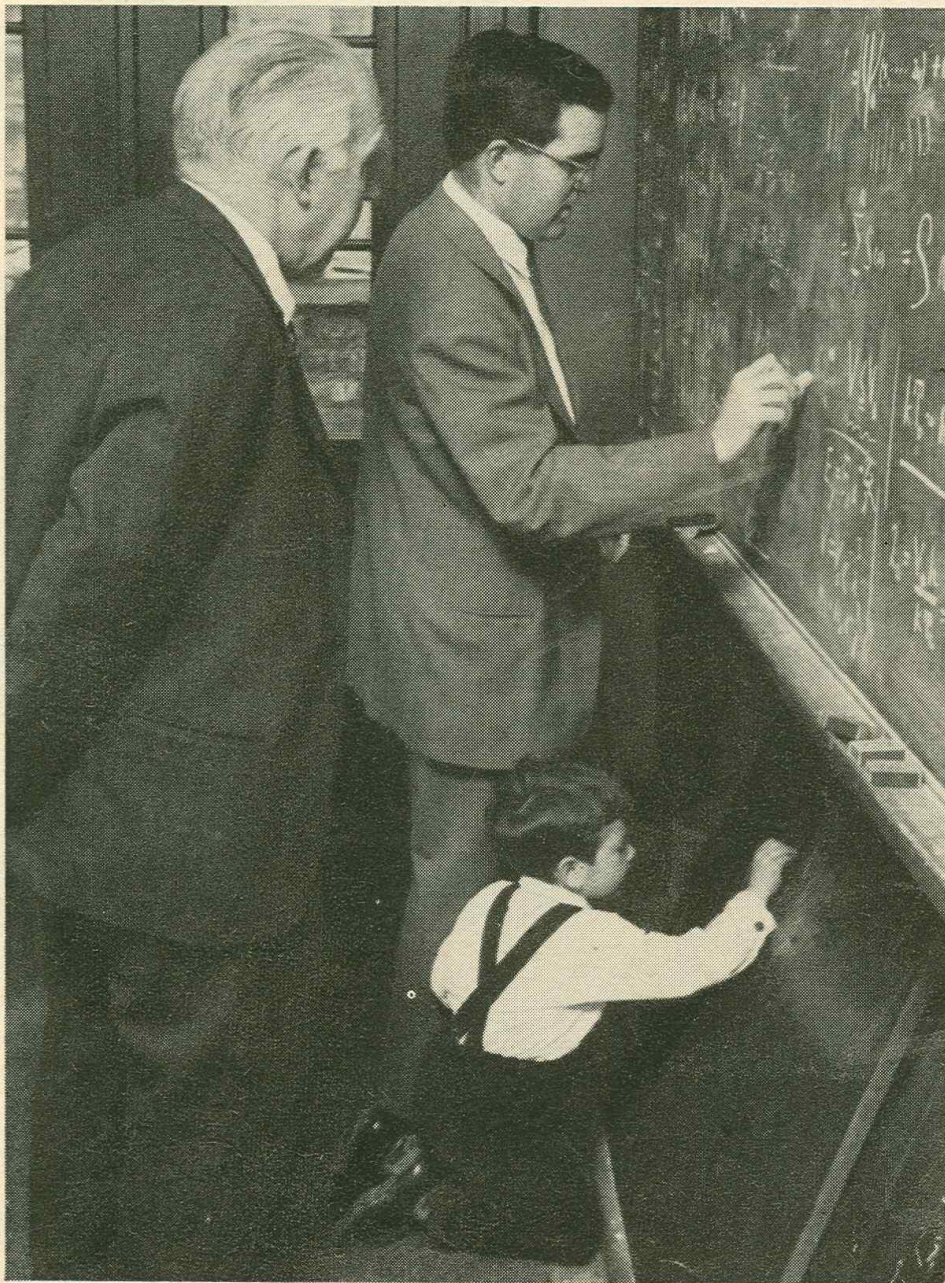
*My father and grandfather on the day  
my father received his Doctorate (1954)*



*Daily life in the family a few years after...*



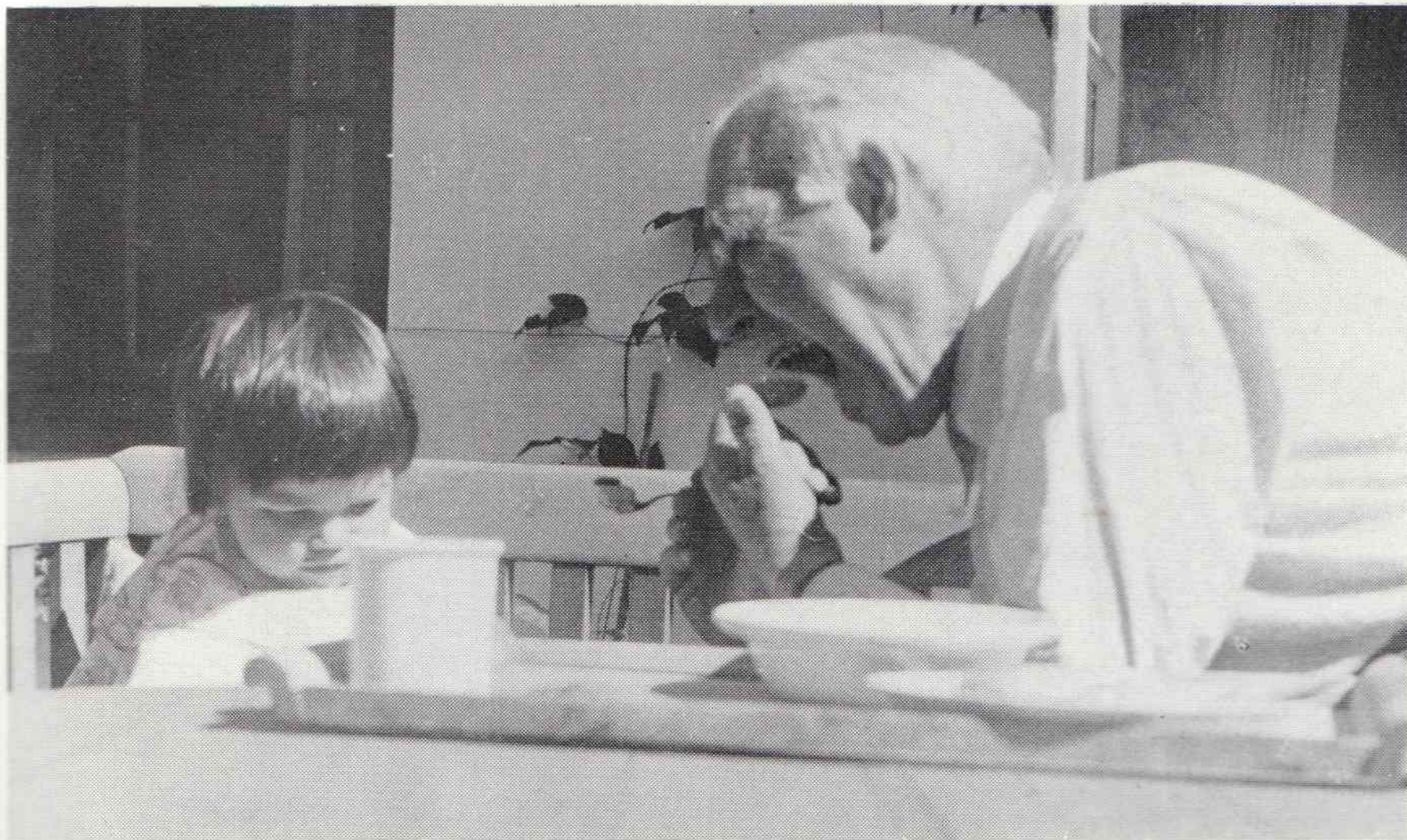




From  
“Life Magazine”  
around 1958

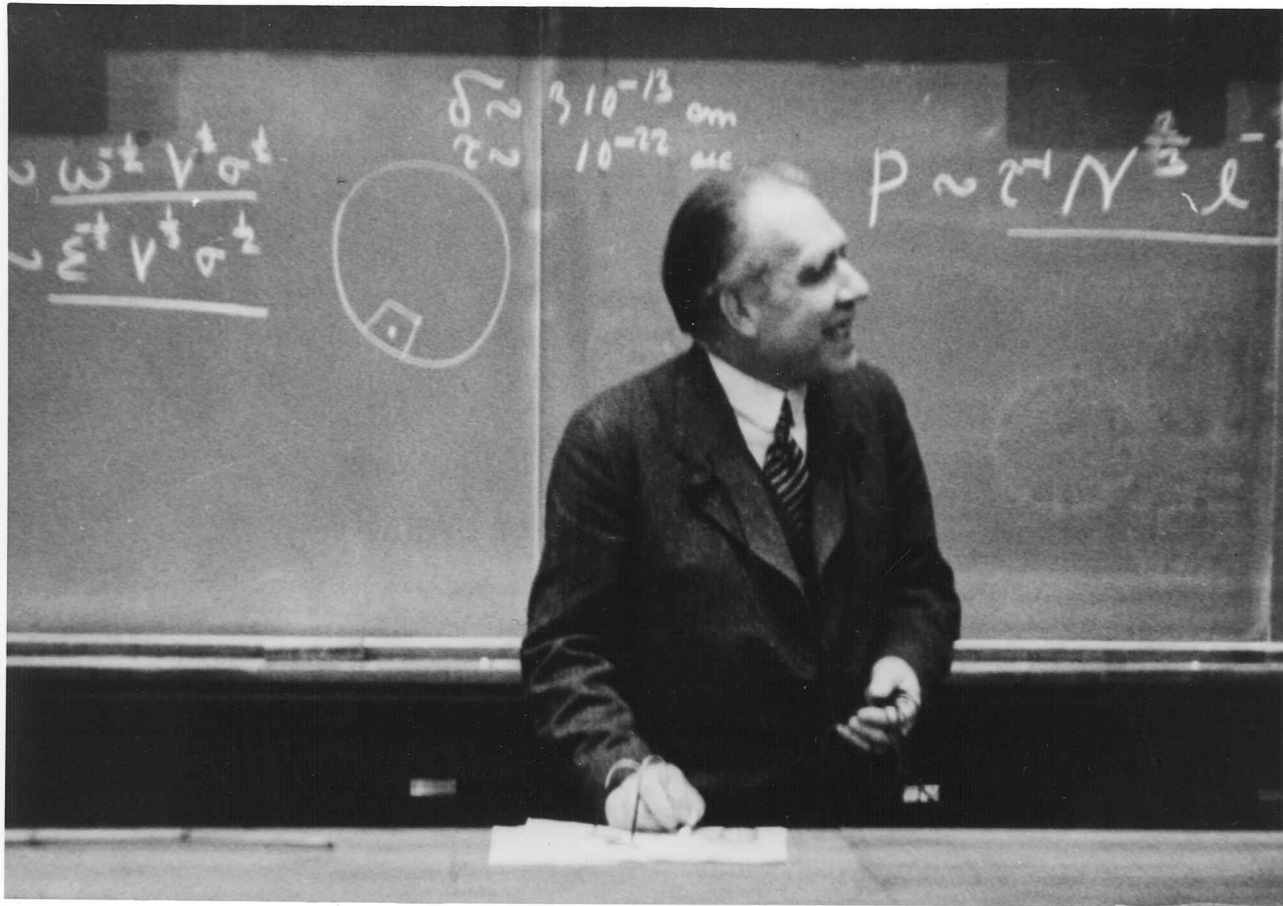
In a blackboard-lined study at home, Bohr watches son Aage write out a calculation while grandson Tomas creeps in unnoticed.

He took active part in our education...

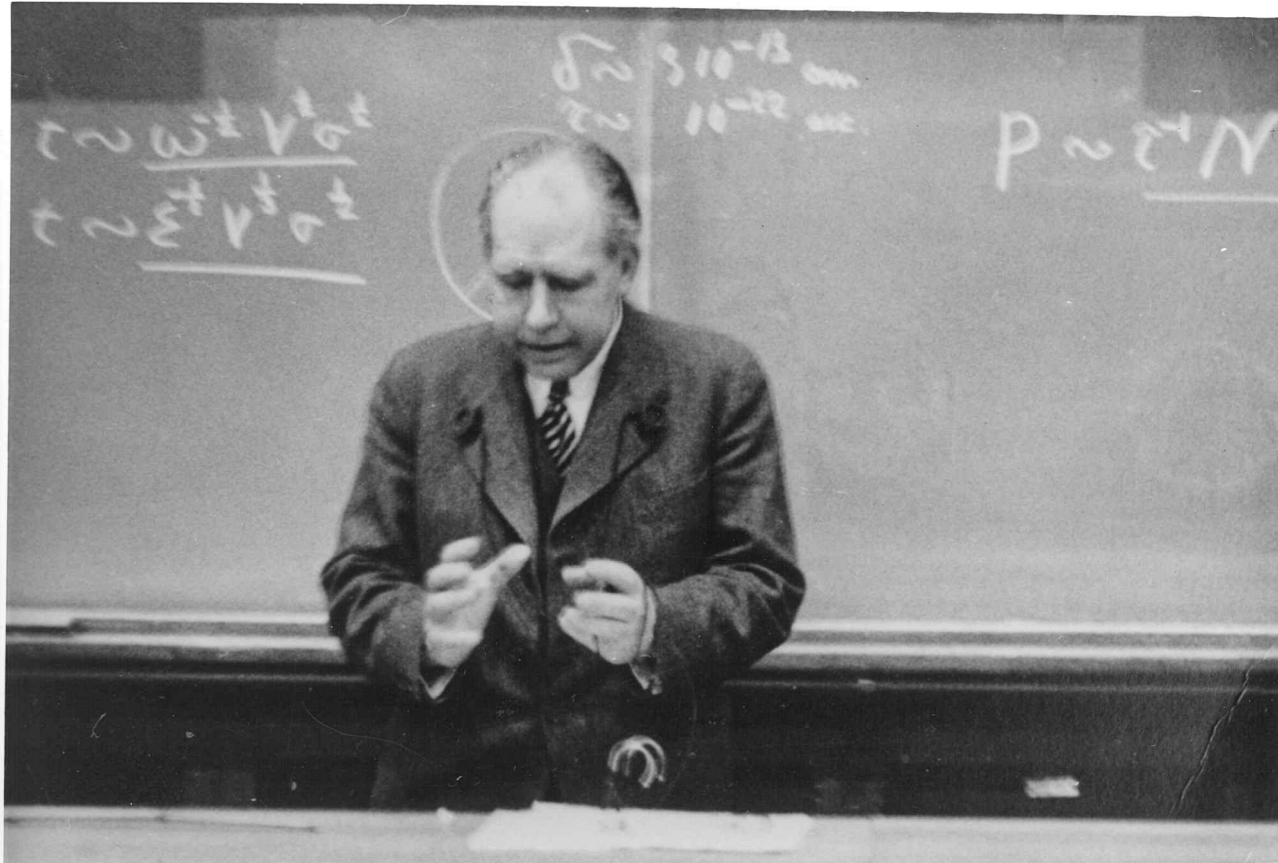


Et barnebarn skal lære at spise

Philosophical outlook  
stories and paradoxes  
surprising comparisons  
never give up



*The Compound nucleus*



... is explained

## *The invention of the Compound Nucleus*

Since we now had a neutron source we were able to repeat and extend some of the experiments which Fermi had done in Rome and which had puzzled us considerably. In particular there was his discovery that slow neutrons had so much more effect on certain nuclei than fast ones. According to what was then believed about nuclei, a neutron should pass clean through the nucleus, with only a small chance of being captured. Hans Bethe in the USA had tried to calculate that chance, and I remember a colloquium in 1935 when some speaker reported on that paper. On that occasion Bohr kept interrupting, and I was beginning to wonder, with some irritation, why he didn't let the speaker finish. Then, in the middle of a sentence, Bohr suddenly stopped and sat down, his face completely dead. We looked at him for several seconds, getting anxious. Had he been taken unwell? But then he suddenly got up and said with an apologetic smile, "Now I understand it".

*O. R. Frisch: What Little I remember (1979)*

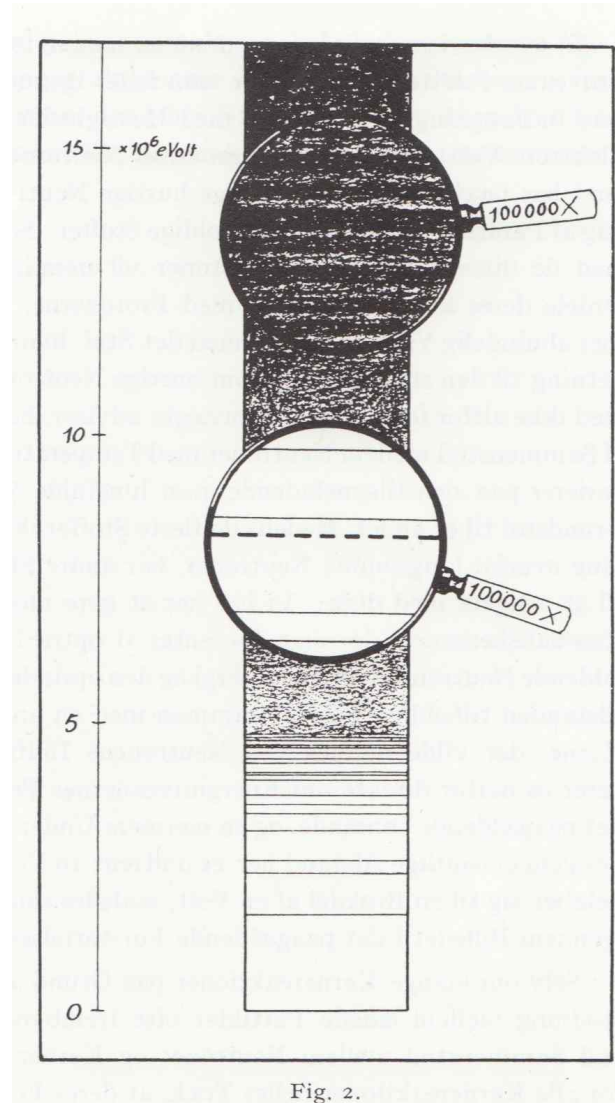
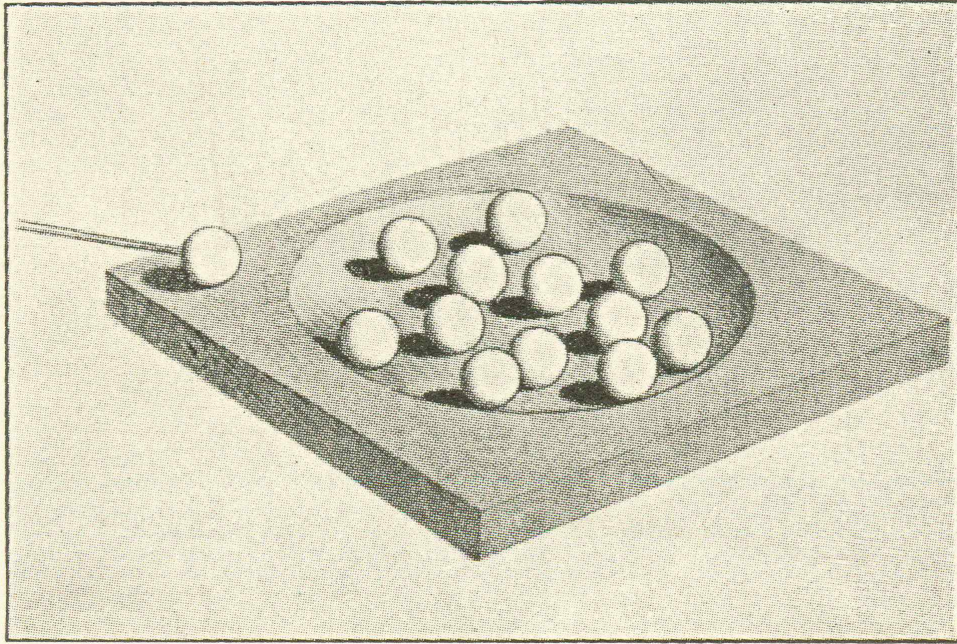


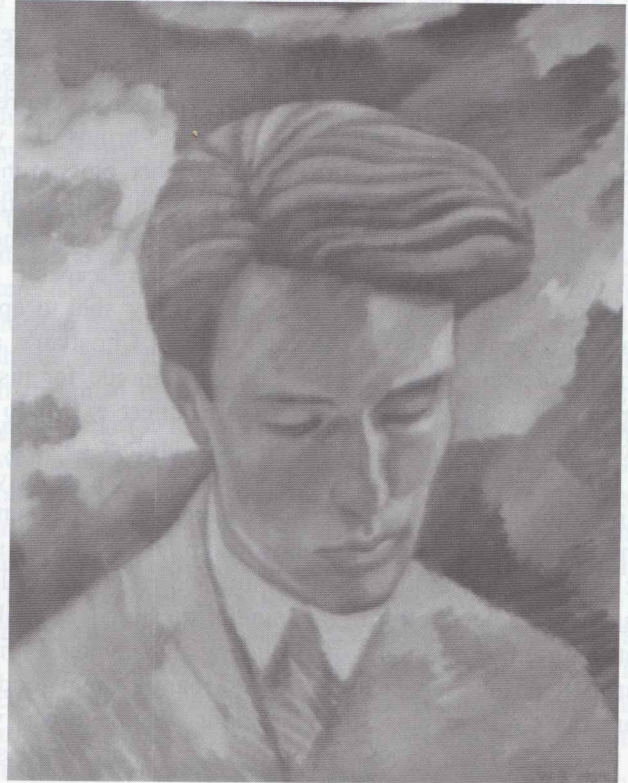
Fig. 2.

*The Compound Nucleus: the nucleus as a complex system with collective modes (1936)*



Julius Paulsen pinx.

Sept. 1934



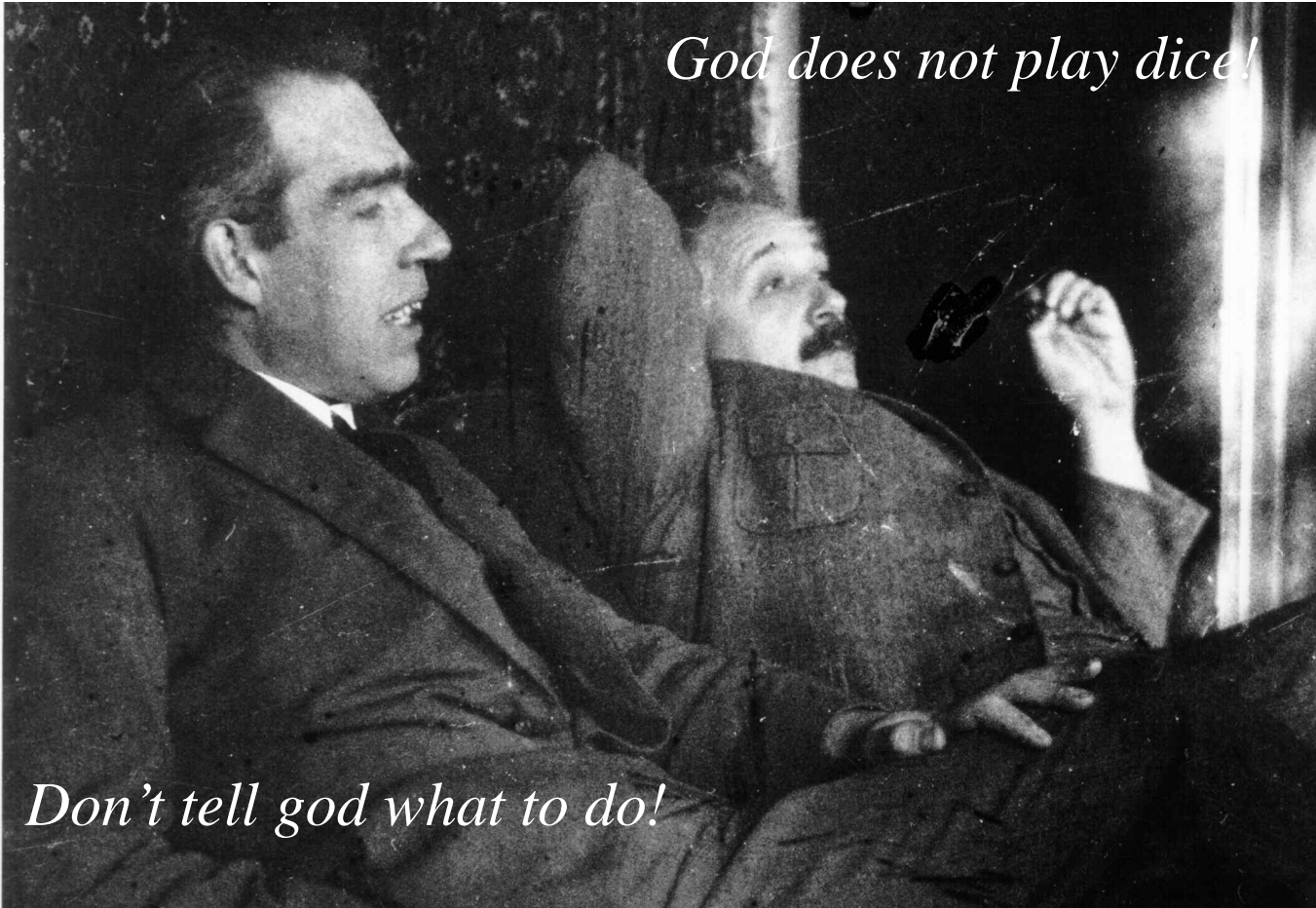
William Scharff pinx.

Okt. 1934



... each of us probably lives  
his strongest life in the  
thoughts of his fellow human  
beings.

*At the departure from home.  
26. August 1934*



*God does not play dice!*

*Don't tell god what to do!*

Going to the top



Never give up !

Keeping things open

*You will therefore understand that I shall not attempt to propose an explanation of the spectral laws; on the contrary I shall try to indicate a way in which it appears possible to bring the spectral laws into close connection with other properties of the elements, which appears equally inexplicable on the basis of the present state of the science.*

From the lecture *On the Spectrum of Hydrogen*  
held at the Danish Physical Society, December 20, 1913

Introducing complementarity -  
don't write more clearly than you think !

*The hindrances [in formulating the quantum laws]... originate above all in the fact that, so to say, every word in the language refers to our ordinary perceptions. In the quantum theory we meet this difficulty at once in the question of the inevitability of the feature of irrationality characterizing the quantum postulate.*

Nature (1928)

1950



Publishing the open letter to UN

# The open letter

We are in a possession of a weapon qualitatively different from any conventional weapon, in fact so strong that it cannot be used as a weapon, only as a deterrent.

The technology needed for making such a bomb is essentially known and cannot be kept secret. We therefore have two possibilities: either to *give* the Russians the secret or to let them find out by themselves (in a short time).

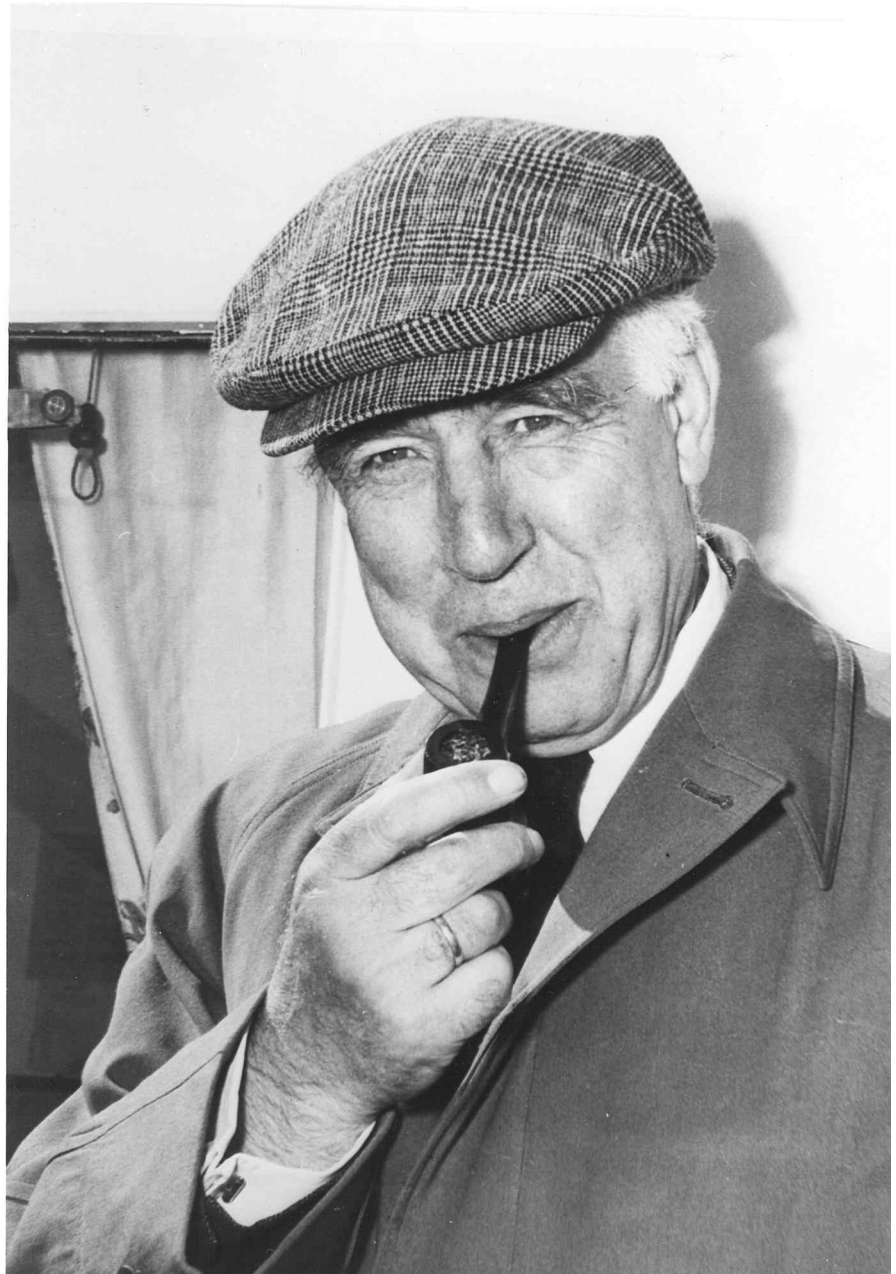
We gain significantly by using the first option if in return we get openness (*lethal to any dictator!*). The well-established international collaboration between scientists can serve as a model.



... a small section from the Open Letter (1950)

*Looking back at those days [end of the war], I find it difficult to convey with sufficient vividness the fervent hopes that the progress of science might initiate a new era of harmonious co-operation between nations, and the anxieties lest any opportunity to promote such a development be forfeited.*

*The end*



1954