The Bohr-Rosenfeld paper on the measurability of electromagnetic field quantities

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Niels Bohr Archive
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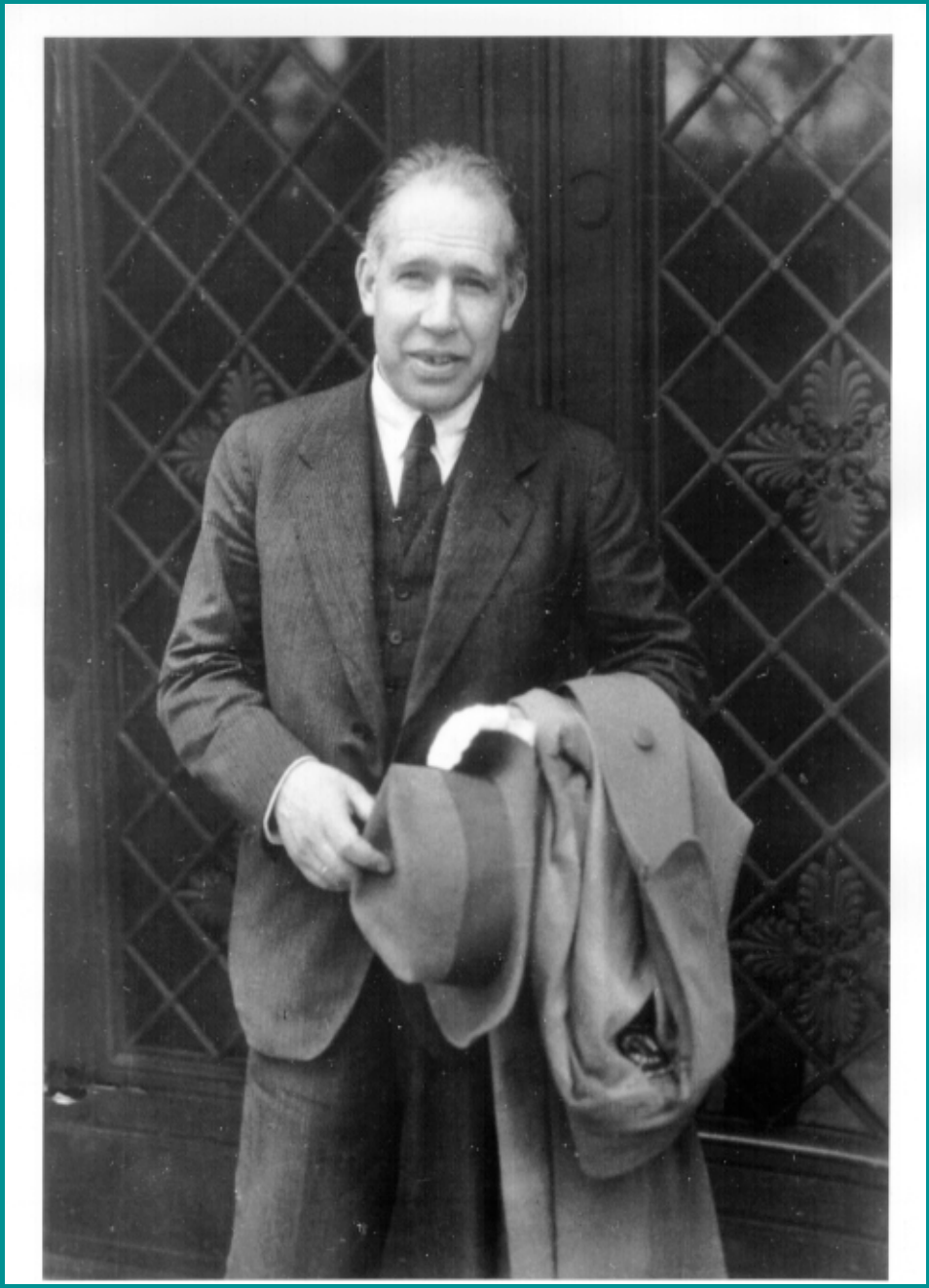
Plan

- Project
- Questions
- Where was Bohr?
- Who was Rosenfeld?
- The Bohr-Rosenfeld paper
- Answers

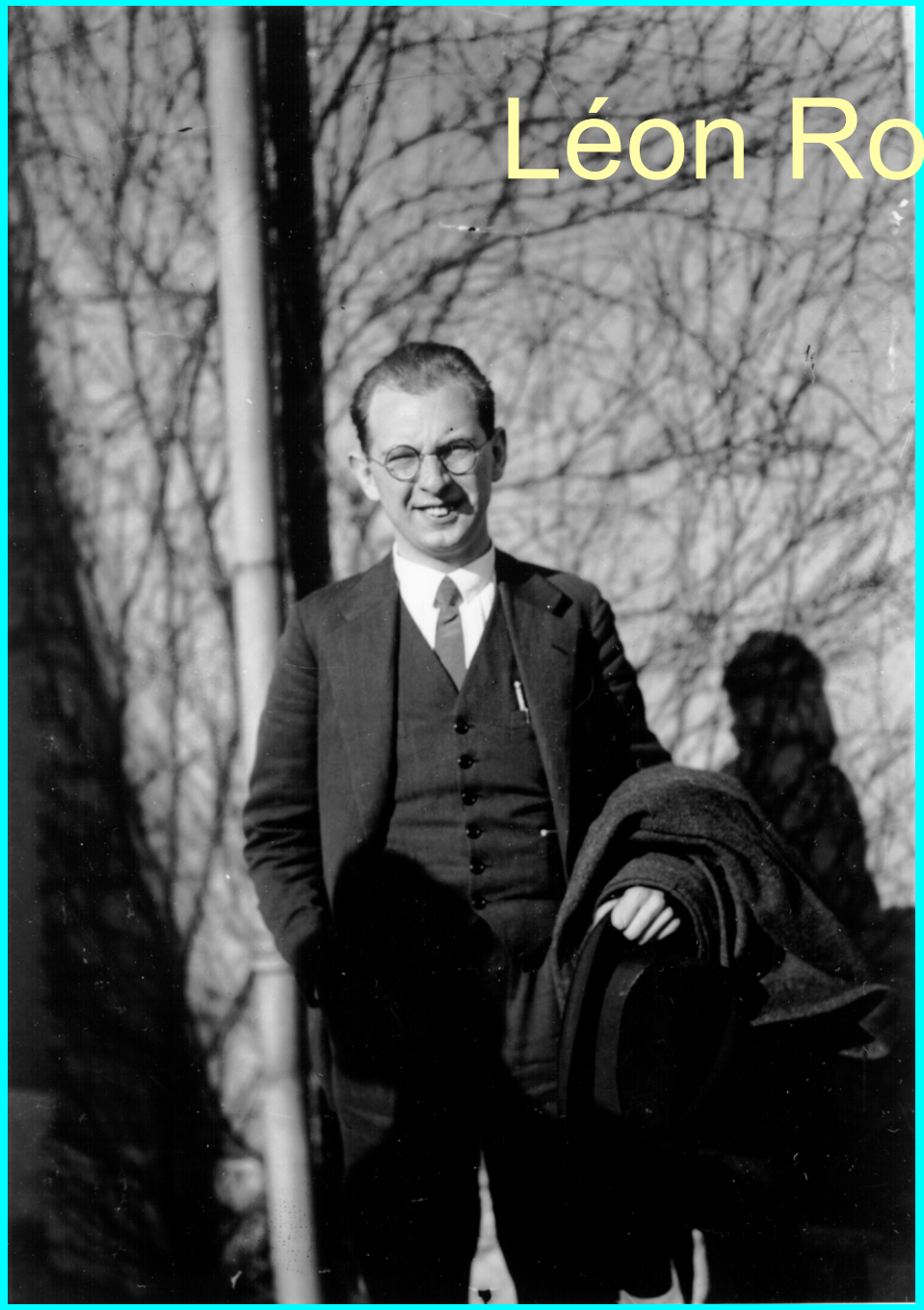
Questions

- The importance of this work in the evolution of Bohr's thought?
- Connection to Bohr-Einstein debate?
- Significance?
- "everybody agrees that it's a masterpiece, but do many read it?" (Rosenfeld 1963)
- The role of complementarity?
- The role of correspondence?
- The role of Bohr and the role of Rosenfeld?



Niels Bohr

- Como 1927: Complementarity
- Solvay 1927 and 1930: Discussions with Einstein
- Popular writings
- Complementarity in biology and psychology



Léon Rosenfeld

- ”poweful command of mathematics without losing sight of the physical facts”
- ”given to philosophical contemplation”
- Bohr about Rosenfeld: ”a man more learned than I”
- Passionate Marxist

Prelude

- Commutation relations of field components:

$$[E_j(\vec{x}_1), H_k(\vec{x}_2)] = -2i\hbar c\,\varepsilon_{jkl}\frac{\partial}{\partial x_1^l}\delta(\vec{x}_1 - \vec{x}_2)$$

  corresponding uncertainty relations?

- Heisenberg 1929:

$$\Delta E_x \cdot \Delta H_y \geq \frac{hc}{(\delta l)^4}$$

The Landau-Peierls paper 1931

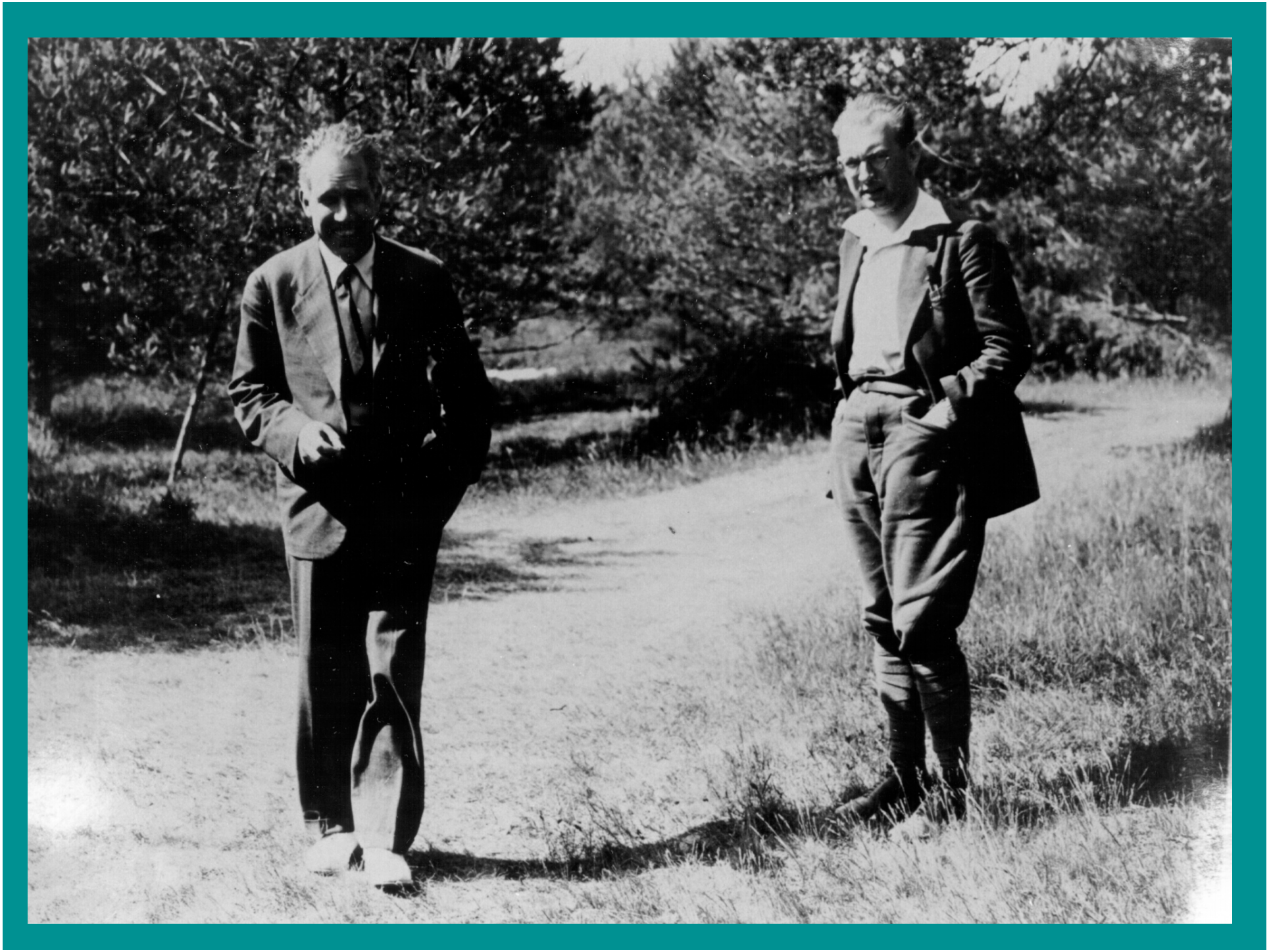
- "Extension of the Uncertainty Principle to Relativistic Quantum theory"

- Additional uncertainty:

$$\Delta E = \Delta H \geq \frac{\sqrt{hc}}{(c\Delta t)^2}$$

Bohr's reaction

”Bitte, bitte, Landau, muss ich nur ein Wort sagen!”



”My first task was to lecture Bohr on the fundamentals of field quantization; the mathematical structure of the commutation relations and the underlying physical assumptions of the theory were subjected to unrelenting scrutiny. After a short time, needless to say, the roles were inverted and he was pointing out to me essential features to which nobody had as yet paid sufficient attention”

Rosenfeld, ”On quantum electrodynamics”, 1955

The Bohr-Rosenfeld paper

- 3 years, 40 pages and 14 proofs later:
- “Zur Frage der Messbarkeit der elektromagnetischen Feldgrössern” (1933)

Commutation relations

$$[E_j(\vec{x}_1), H_k(\vec{x}_2)] = -2ihc\varepsilon_{jkl}\frac{\partial}{\partial x_1^l}\delta(\vec{x}_1 - \vec{x}_2)$$

Averaged fields

$$\overline{E}_x^G = \frac{1}{VT}\int_{(T)} dt \int_{(V)} dv E_x$$

The test body

Classical ”measurement instrument”:

Finite distribution of charge with liniar extension large compared with atomic dimensions

Momentum measurement

$$\overline{E}_x \cdot \rho VT = p_x'' - p_x'$$

$$\Delta p_x \cdot \Delta x \geq h$$

Fluctuations

- Zero-field fluctuations
- Fluctuations produced by the test body

”the main point of our paper [is that] the field fluctuations in themselves do not entail any fundamental limitation to field measurements, but only to the possibility of tracing the results back to the field sources”

Bohr to Heisenberg 1934

Concluding remarks

- Yet another complementarity!
- Correspondence
- Significance
- Complete neglection by commentators on Bohr's philosophy: Difficult technique and specificity
- Significance to Bohr: exercise, challenge

  To Pauli and Heisenberg: reassurance about consistency and foundation of QED
- Bohr, the intuitive — Rosenfeld, the calculator

”this result should properly be regarded as an immediate consequence of the fact that both the quantum electromagnetic formalism and the viewpoints on which the possibilities of testing this formalism are to be assessed have as their common foundation the correspondence argument”