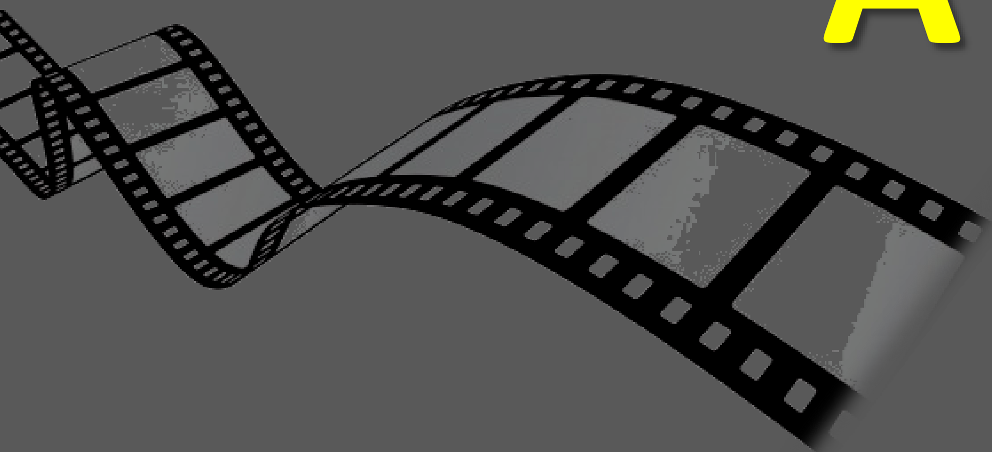
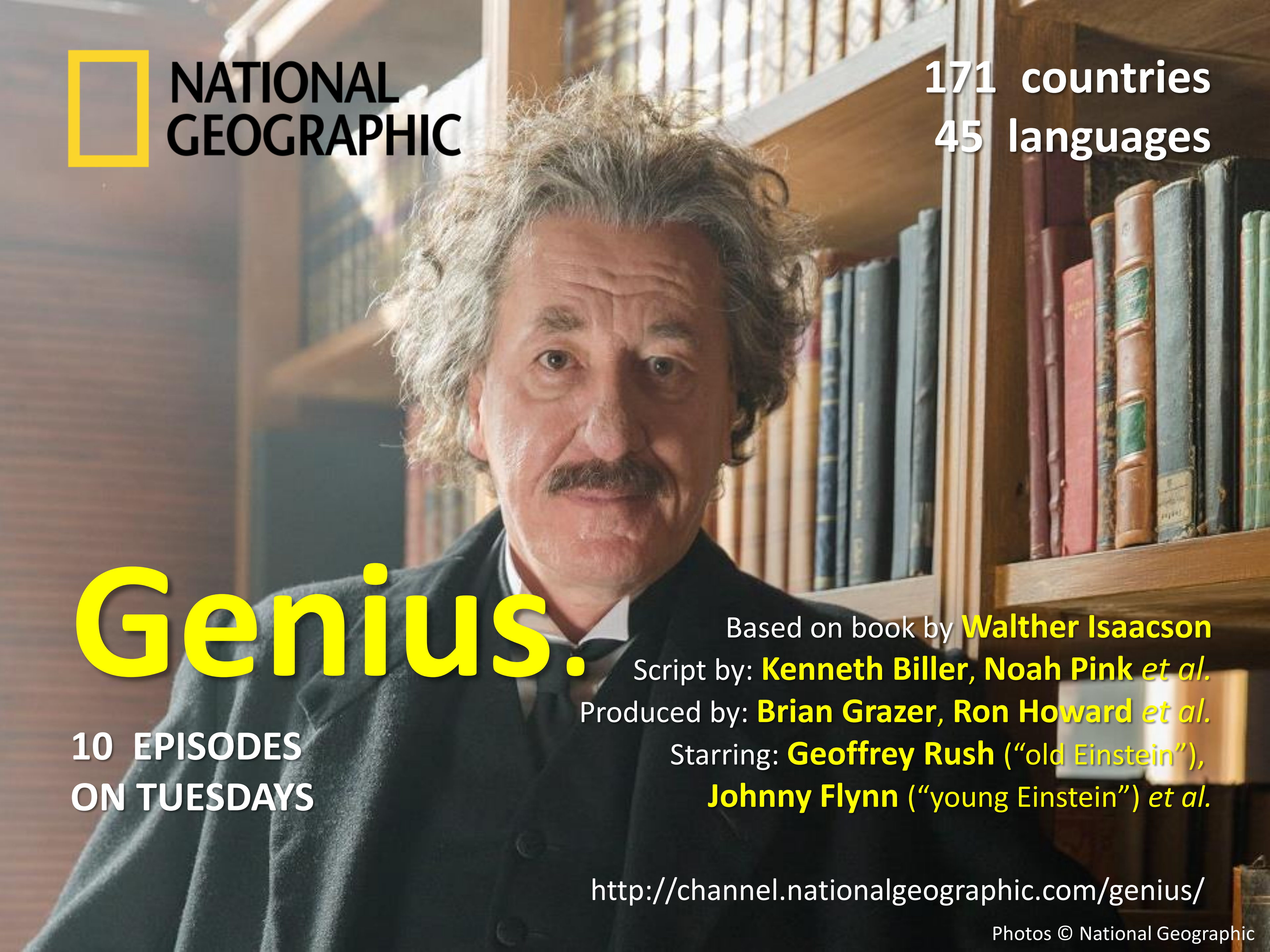


# A physicist meets filmmakers

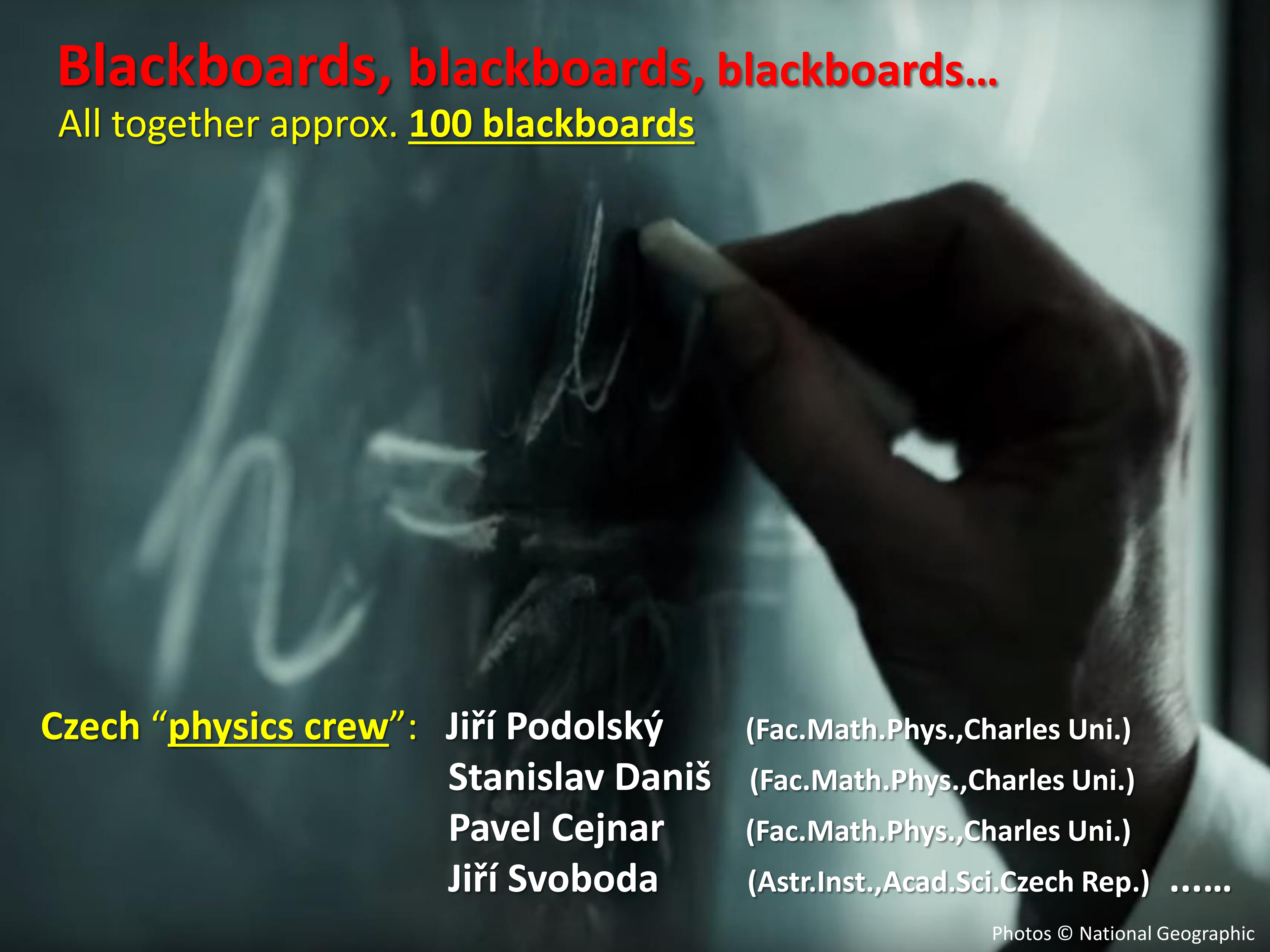
**Pavel Cejnar**

Inst. Particle & Nuclear Physics, Fac. Math.Phys., Charles Uni. Prague


NATIONAL GEOGRAPHIC
171 countries
45 languages
Genius.
10 EPISODES
ON TUESDAYS
Based on book by Walther Isaacson
Script by: Kenneth Biller, Noah Pink et al.
Produced by: Brian Grazer, Ron Howard et al.
Starring: Geoffrey Rush ("old Einstein"),
Johnny Flynn ("young Einstein") et al.
http://channel.nationalgeographic.com/genius/
Photos © National Geographic


Series shot in Czechia!
Staff: 250 – 400 people
95 % Czech crew
Photos © National Geographic


Physics plays the "central role"!
Czech "physics crew": Jiří Podolský (Fac.Math.Phys.,Charles Uni.)
Stanislav Daniš (Fac.Math.Phys.,Charles Uni.)
Pavel Cejnar (Fac.Math.Phys.,Charles Uni.)
Jiří Svoboda (Astr.Inst.,Acad.Sci.Czech Rep.) ......
Photos © National Geographic



# Blackboards, blackboards, blackboards...

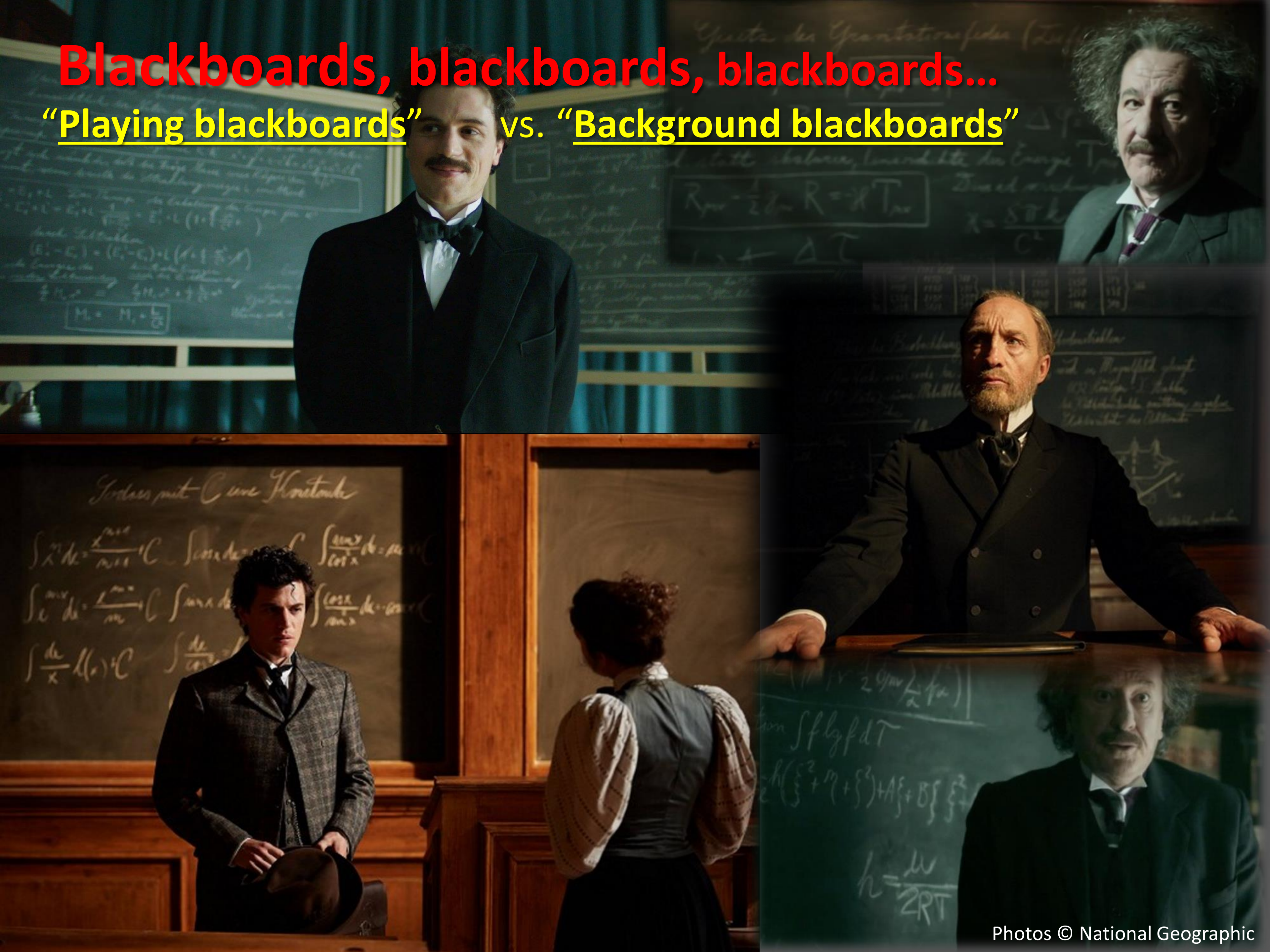
All together approx. **100 blackboards**

**Czech "physics crew":**

| | |
|---|---|
| Jiří Podolský | (Fac.Math.Phys.,Charles Uni.) |
| Stanislav Daniš | (Fac.Math.Phys.,Charles Uni.) |
| Pavel Cejnar | (Fac.Math.Phys.,Charles Uni.) |
| Jiří Svoboda | (Astr.Inst.,Acad.Sci.Czech Rep.) …… |

# Blackboards, blackboards, blackboards…

"**Playing blackboards**" vs. "**Background blackboards**"



Photos © National Geographic

# Blackboards, blackboards, blackboards…

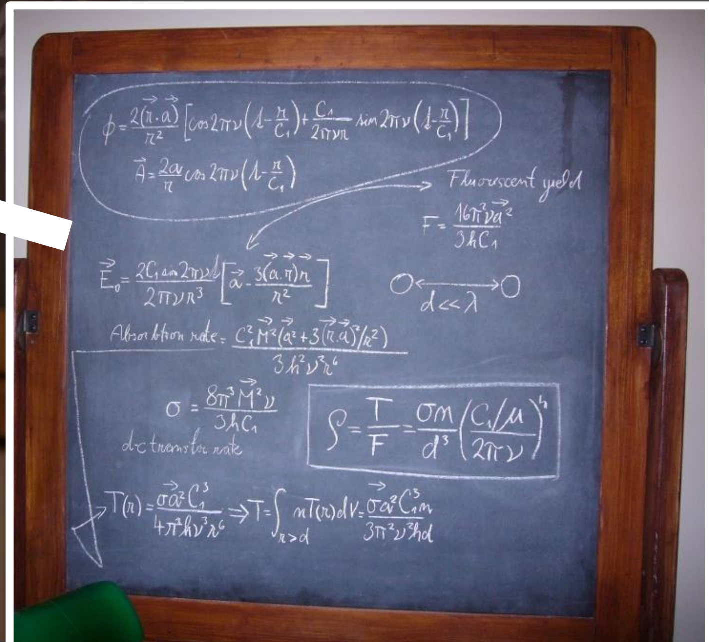
**Background blackboard:  Example 1**


# Blackboards, blackboards, blackboards…

**Background blackboard: Example 1**



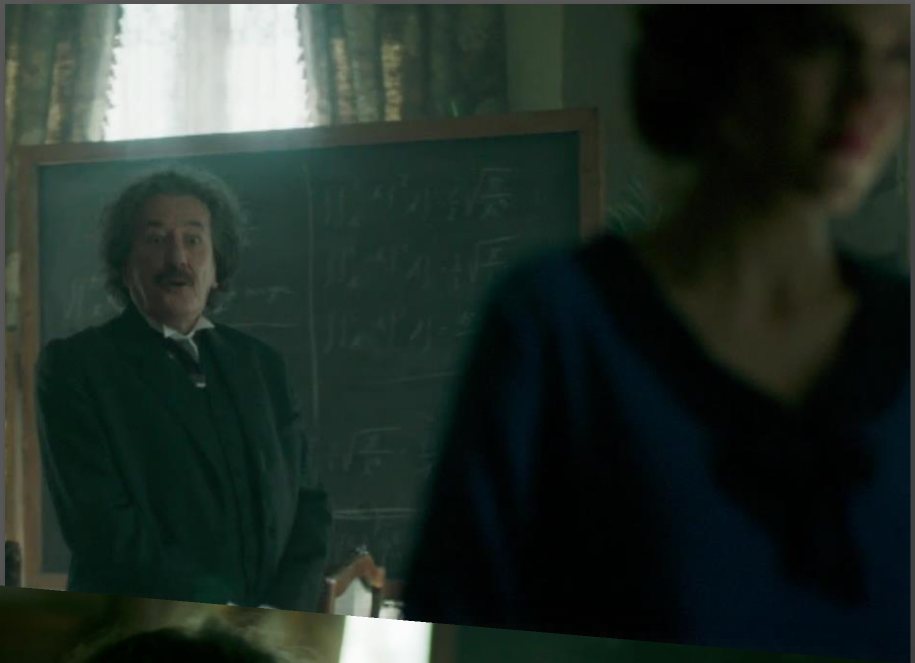
Robert Oppenheimer's blackbord
– 1950 work on photosynthesis

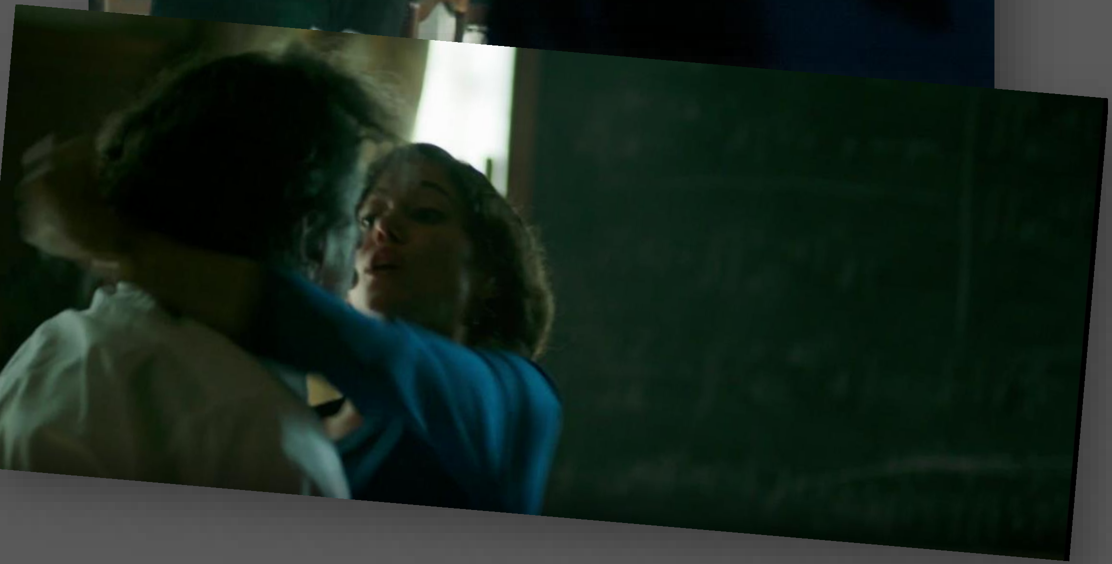


# Blackboards, blackboards, blackboards…

## Background blackboard:  Example 2

**Episode 1, erotic scene, Berlin 1922**

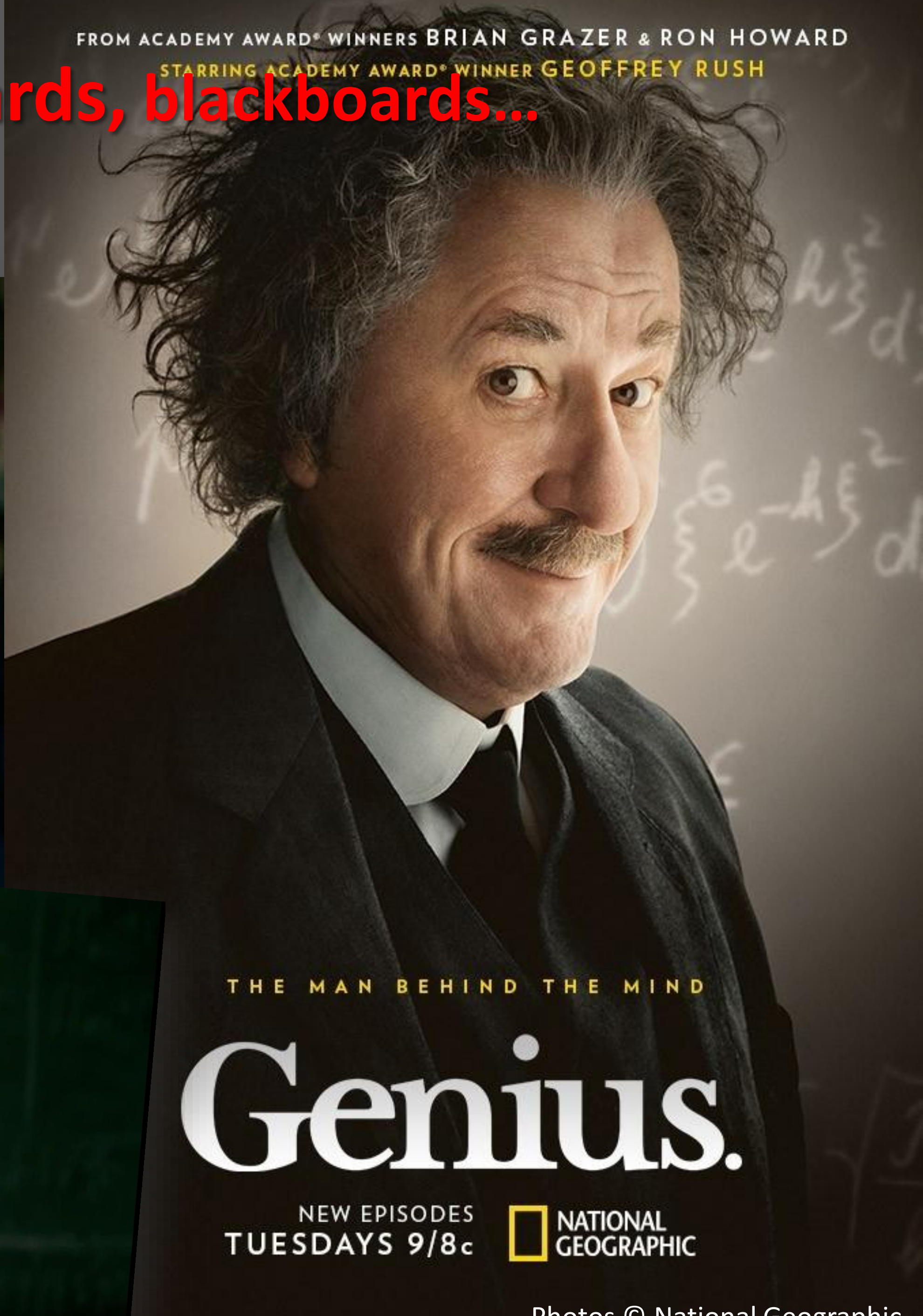




# Blackboards, blackboards, blackboards…

**Background blackboard: Example 2**

**Episode 1, erotic scene, Berlin 1922**

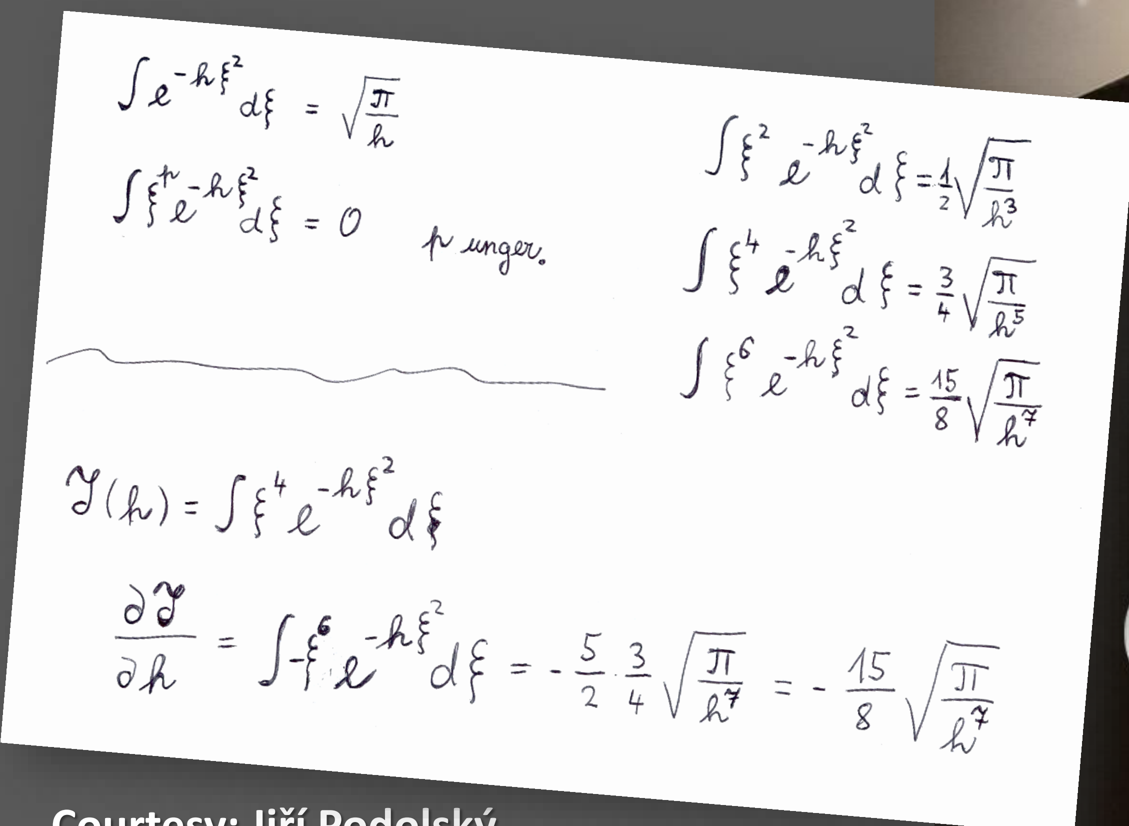



Photos © National Geographic

# Blackboards, blackboards, blackboards…

**Background blackboard: Example 2**

**Episode 1, erotic scene, Berlin 1922**



$$\int e^{-h\xi^2} d\xi = \sqrt{\frac{\pi}{h}}$$

$$\int \xi^p e^{-h\xi^2} d\xi = 0 \qquad p \text{ unger.}$$

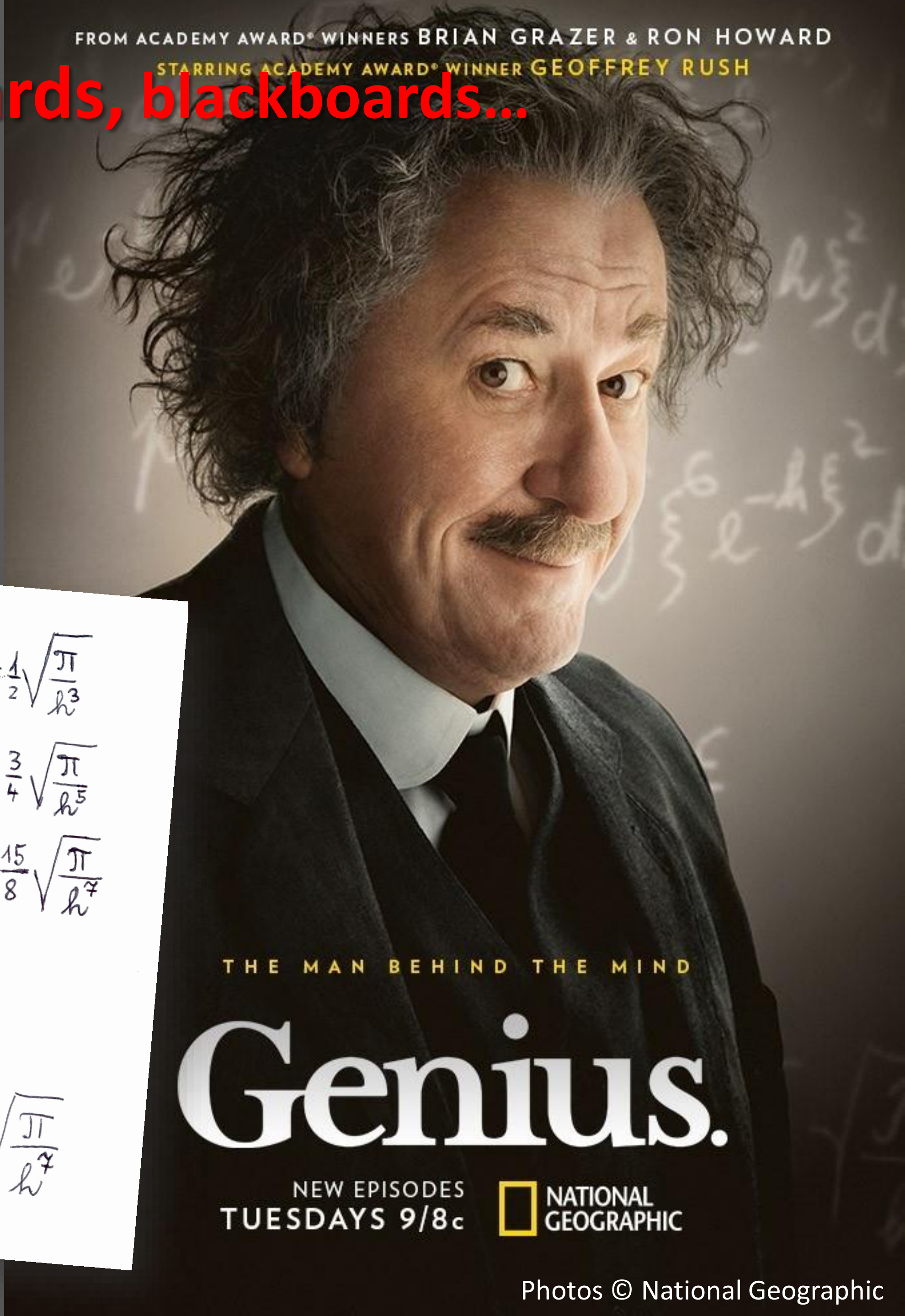
$$\int \xi^2 e^{-h\xi^2} d\xi = \frac{1}{2}\sqrt{\frac{\pi}{h^3}}$$

$$\int \xi^4 e^{-h\xi^2} d\xi = \frac{3}{4}\sqrt{\frac{\pi}{h^5}}$$

$$\int \xi^6 e^{-h\xi^2} d\xi = \frac{15}{8}\sqrt{\frac{\pi}{h^7}}$$

$$\mathcal{J}(h) = \int \xi^4 e^{-h\xi^2} d\xi$$

$$\frac{\partial \mathcal{J}}{\partial h} = \int -\xi^6 e^{-h\xi^2} d\xi = -\frac{5}{2}\cdot\frac{3}{4}\sqrt{\frac{\pi}{h^7}} = -\frac{15}{8}\sqrt{\frac{\pi}{h^7}}$$

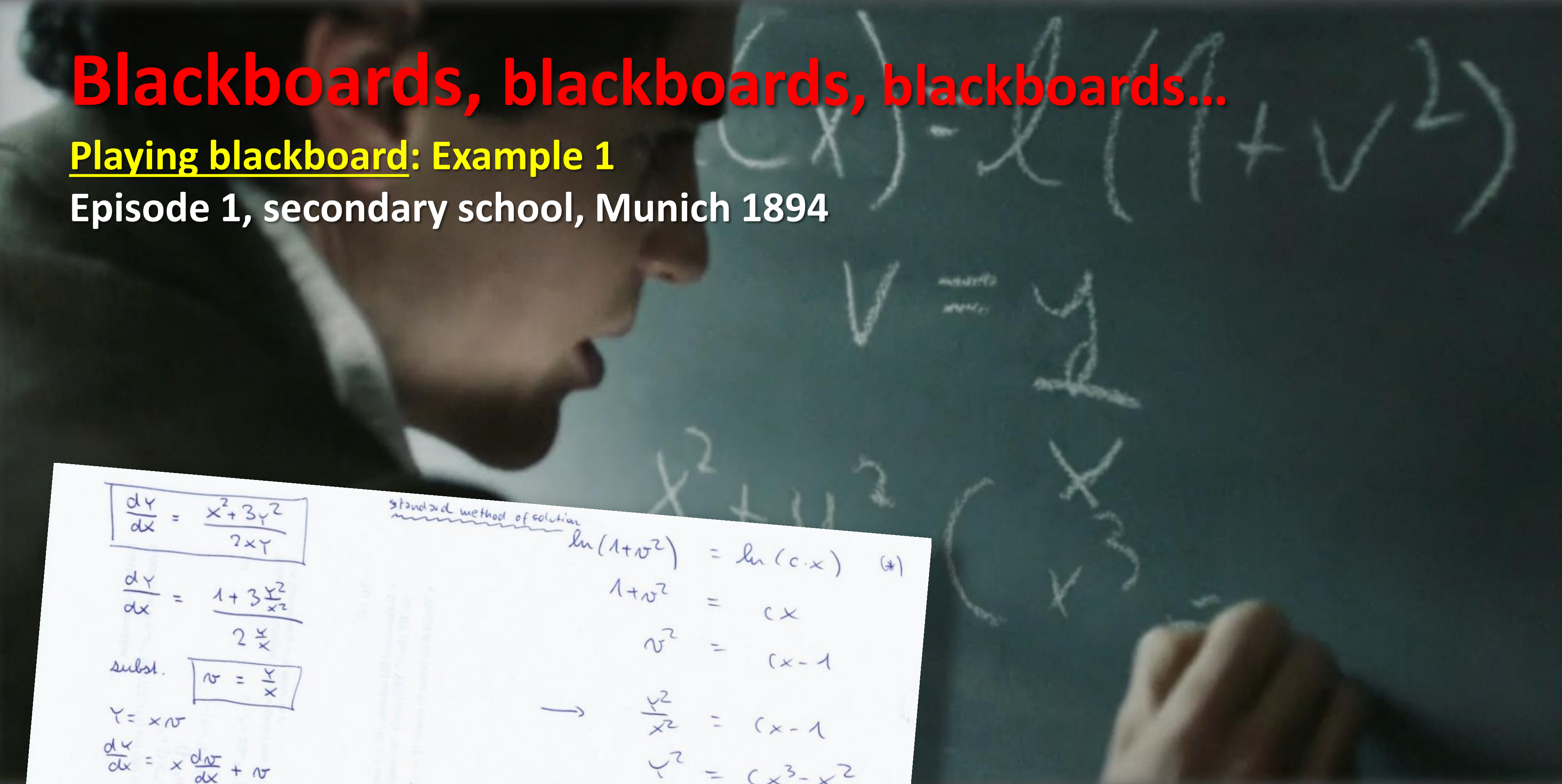


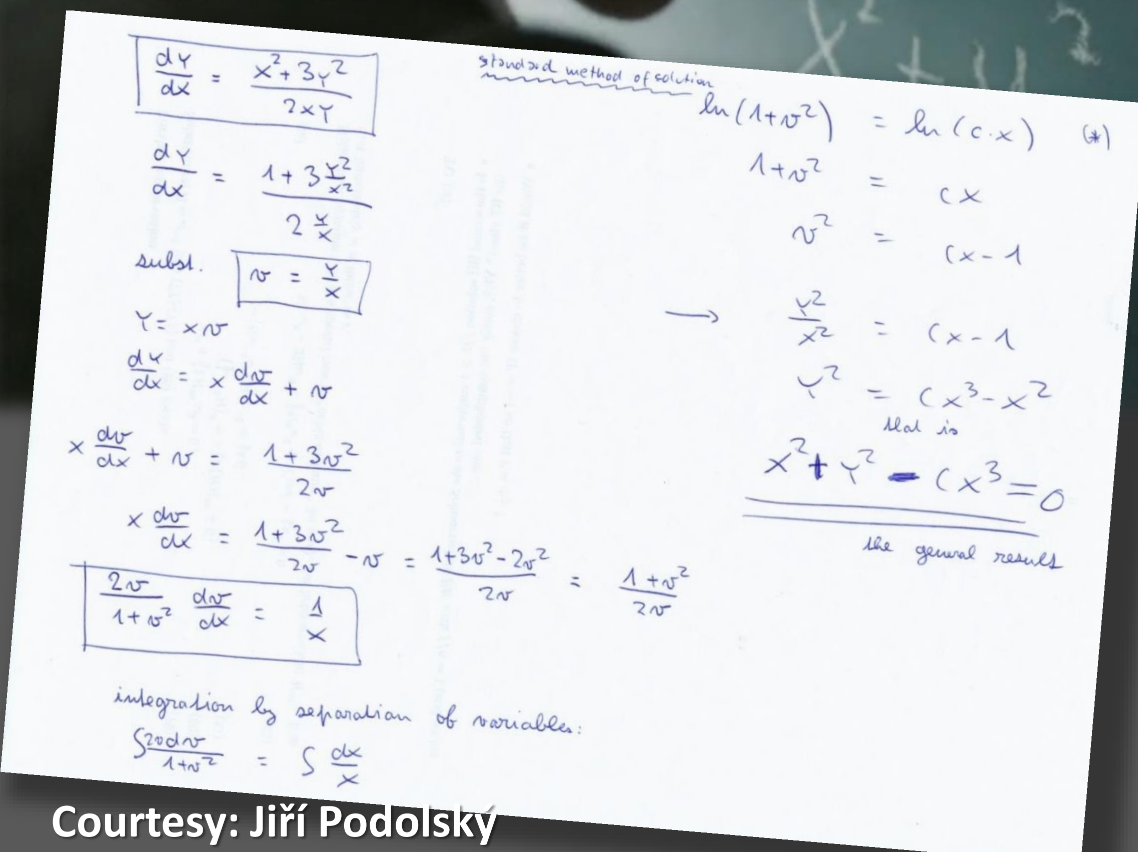

Courtesy: Jiří Podolský

# Blackboards, blackboards, blackboards…

## Playing blackboard: Example 1

**Episode 1, secondary school, Munich 1894**

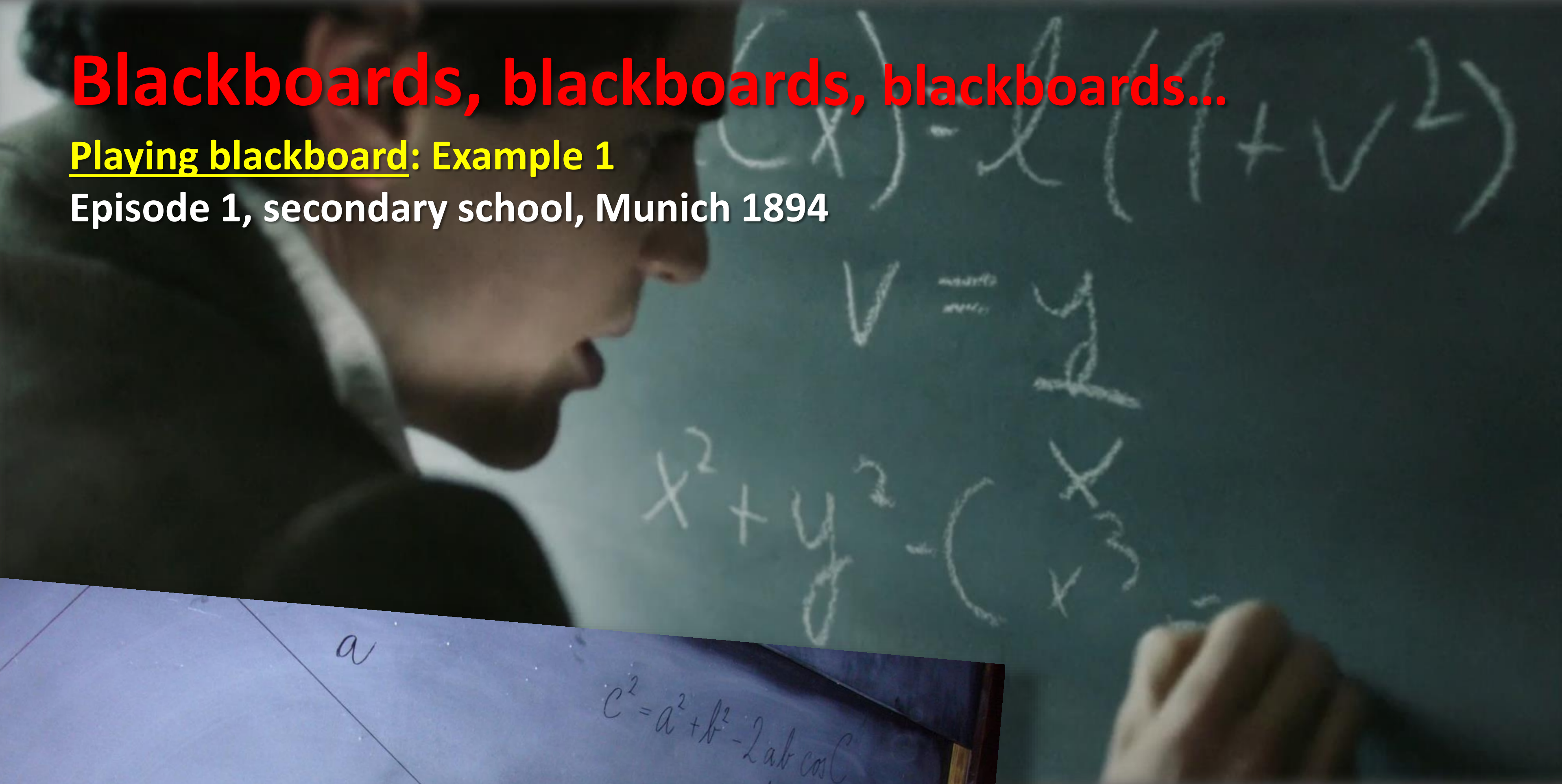





$l = ln$

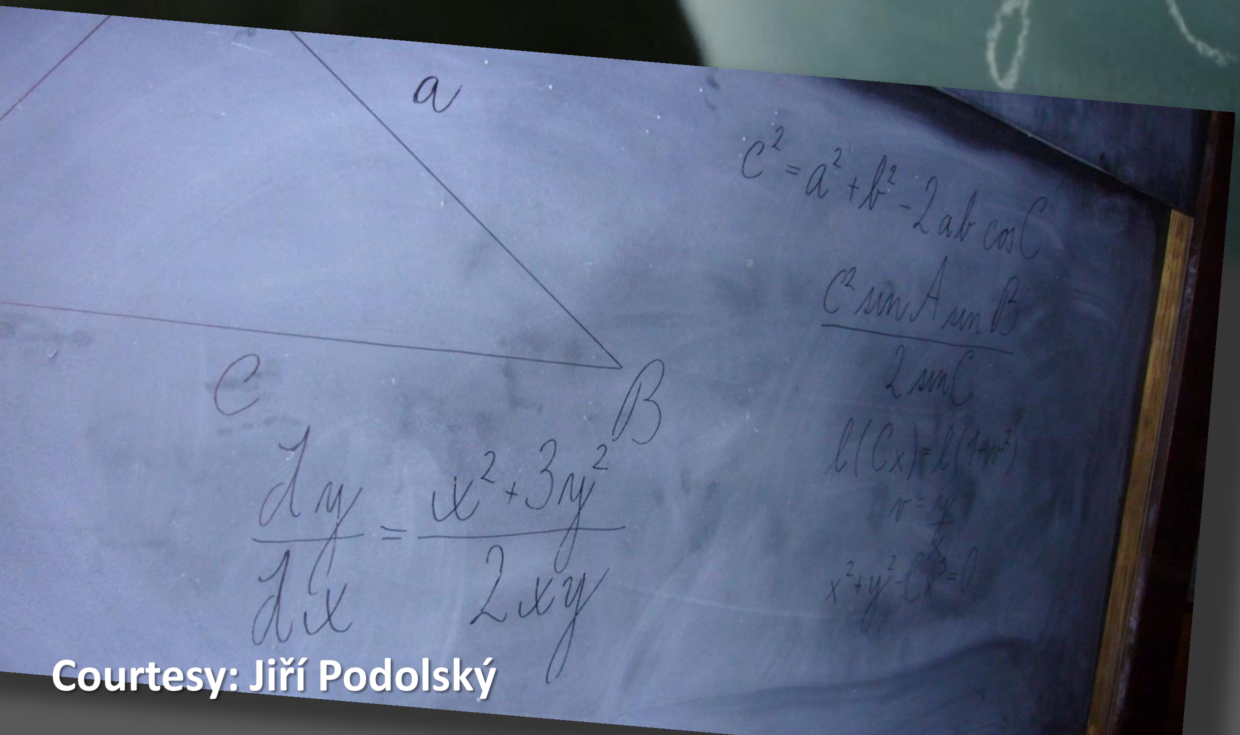
**Courtesy: Jiří Podolský**

# Blackboards, blackboards, blackboards…



**Playing blackboard: Example 1**

**Episode 1, secondary school, Munich 1894**

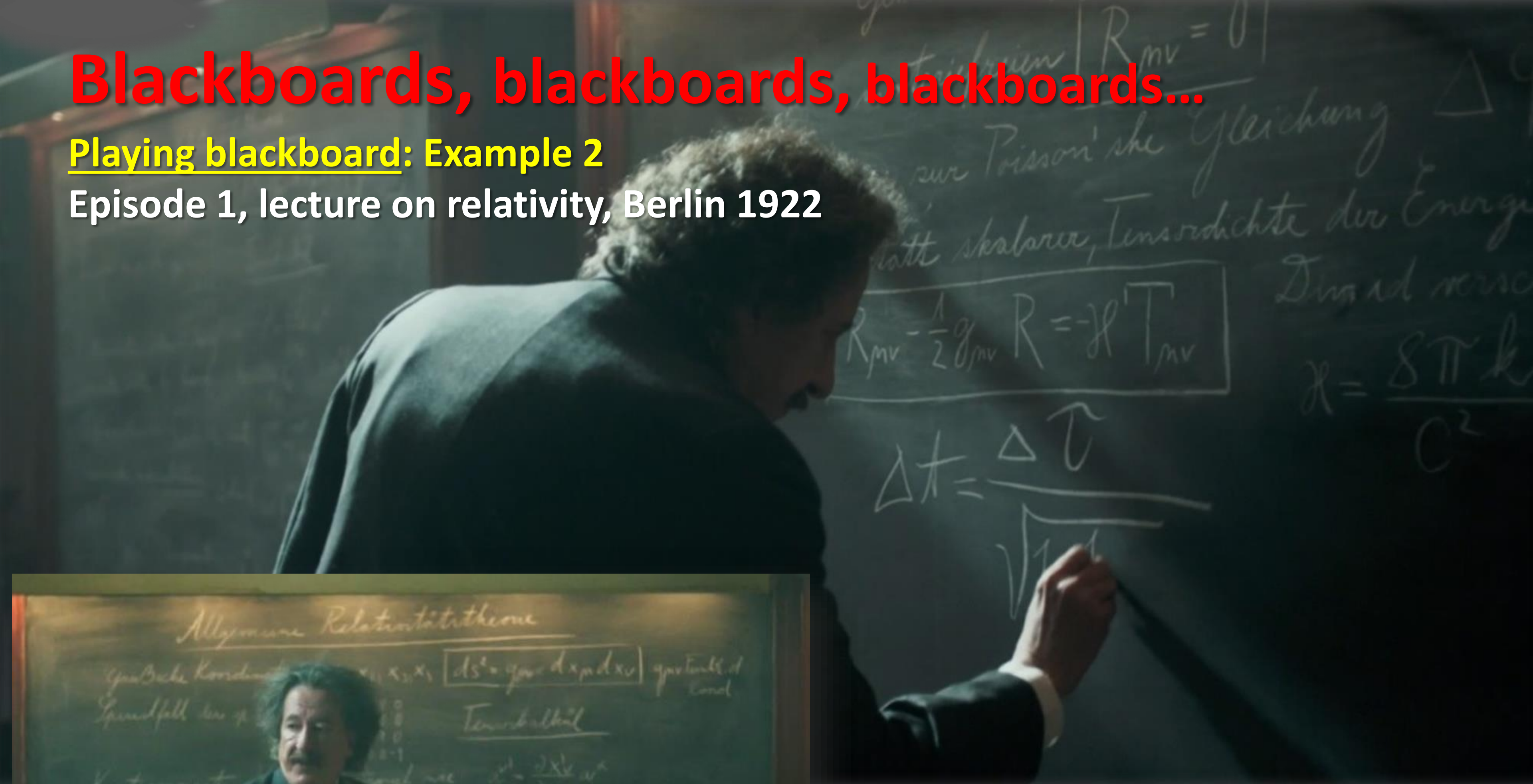



Courtesy: Jiří Podolský

$l = ln$

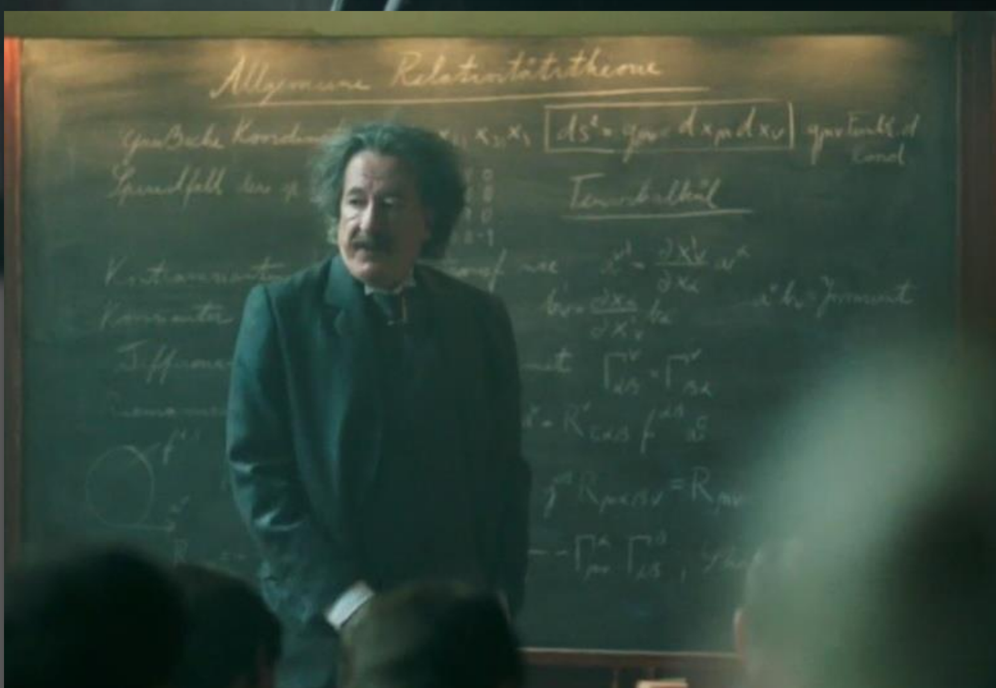
Photos © National Geographic

# Blackboards, blackboards, blackboards…



**Playing blackboard: Example 2**

Episode 1, lecture on relativity, Berlin 1922



Photos © National Geographic

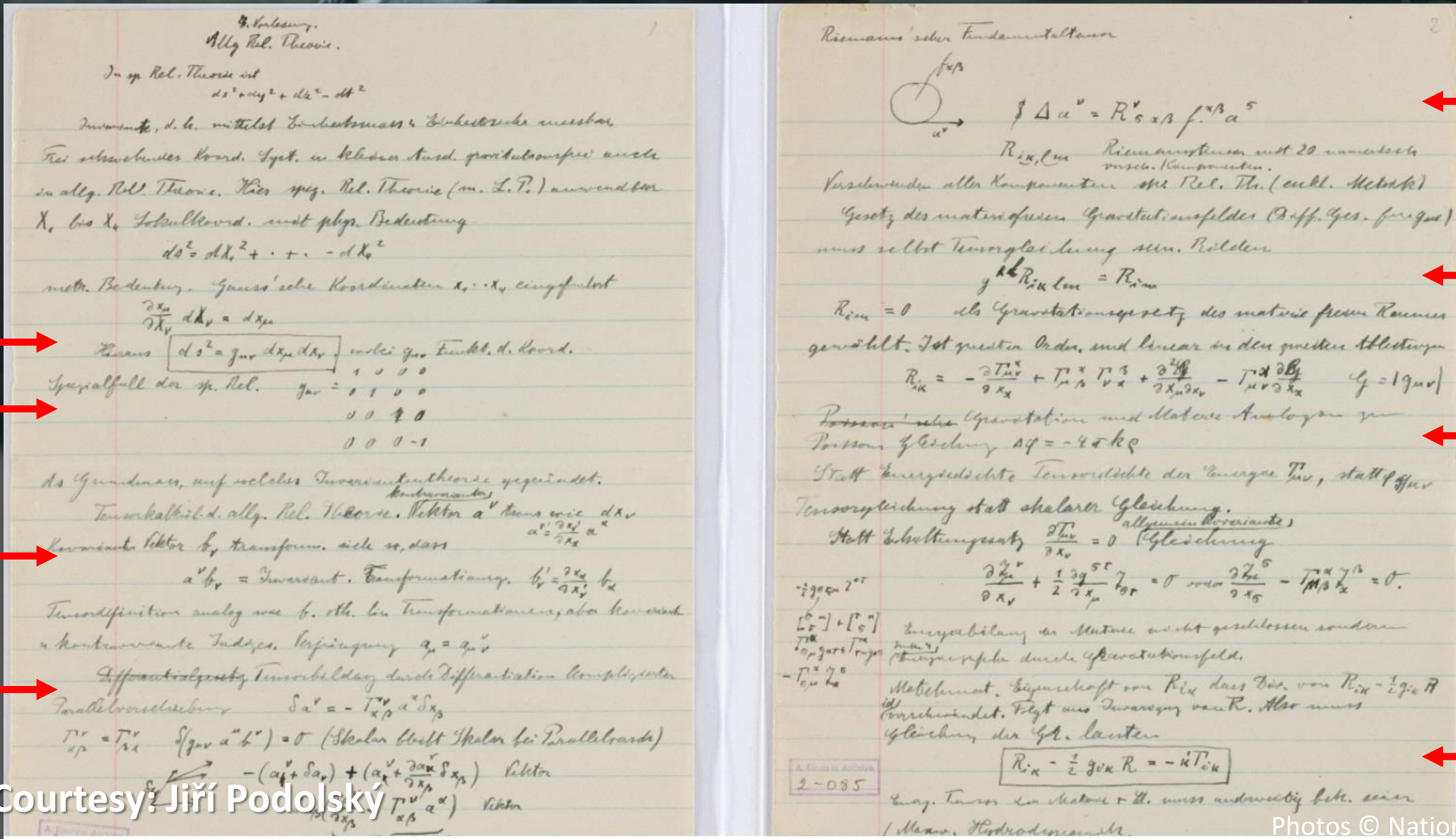
# Blackboards, blackboards, blackboards…

## Playing blackboard: Example 2

### Episode 1, lecture on relativity, Berlin 1922

Manuscript *Über die spezielle und allgemeine Relativitätstheorie 1. Vorlesung*, 1921

Albert Einstein Archives, The Hebrew University of Jerusalem
http://www.albert-einstein.org/


Allg. Rel. Theorie.

Riemann'scher Fundamentaltensor

$$R_{ik} - \frac{1}{2} g_{ik} R = -\kappa T_{ik}$$

Courtesy: Jiří Podolský

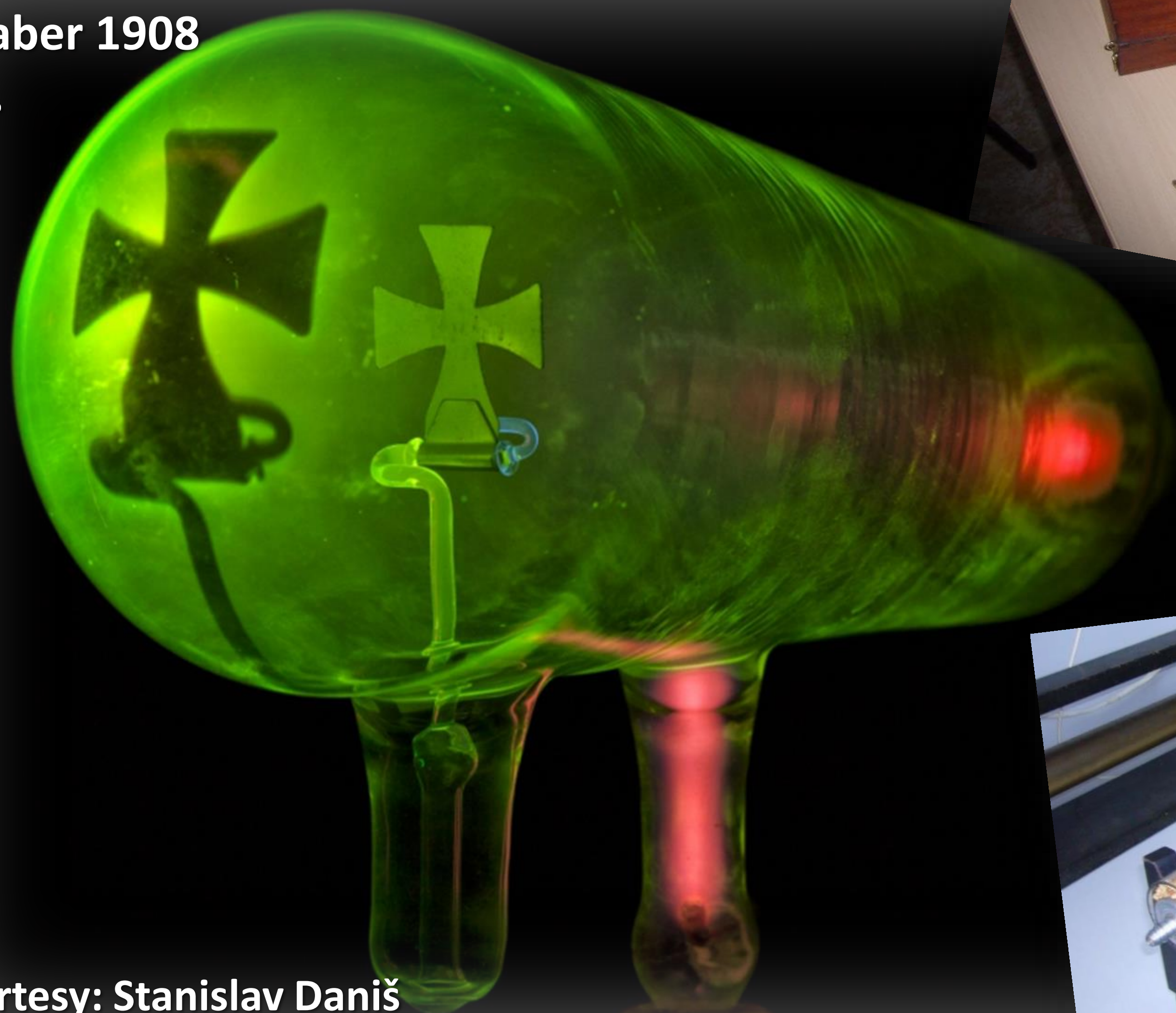
# Blackboards, blackboards, blackboards…

## Playing blackboard: Example 2

Episode 1, lecture on relativity, Berlin 1922

# Experiments, instruments, labs…

**Röntgen 1895**
**Lenard 1901**
**Sklodowska, Curie 1898, 1902**
**Haber 1908**
**….**



Courtesy: Stanislav Daniš

# Experiments, instruments, labs...

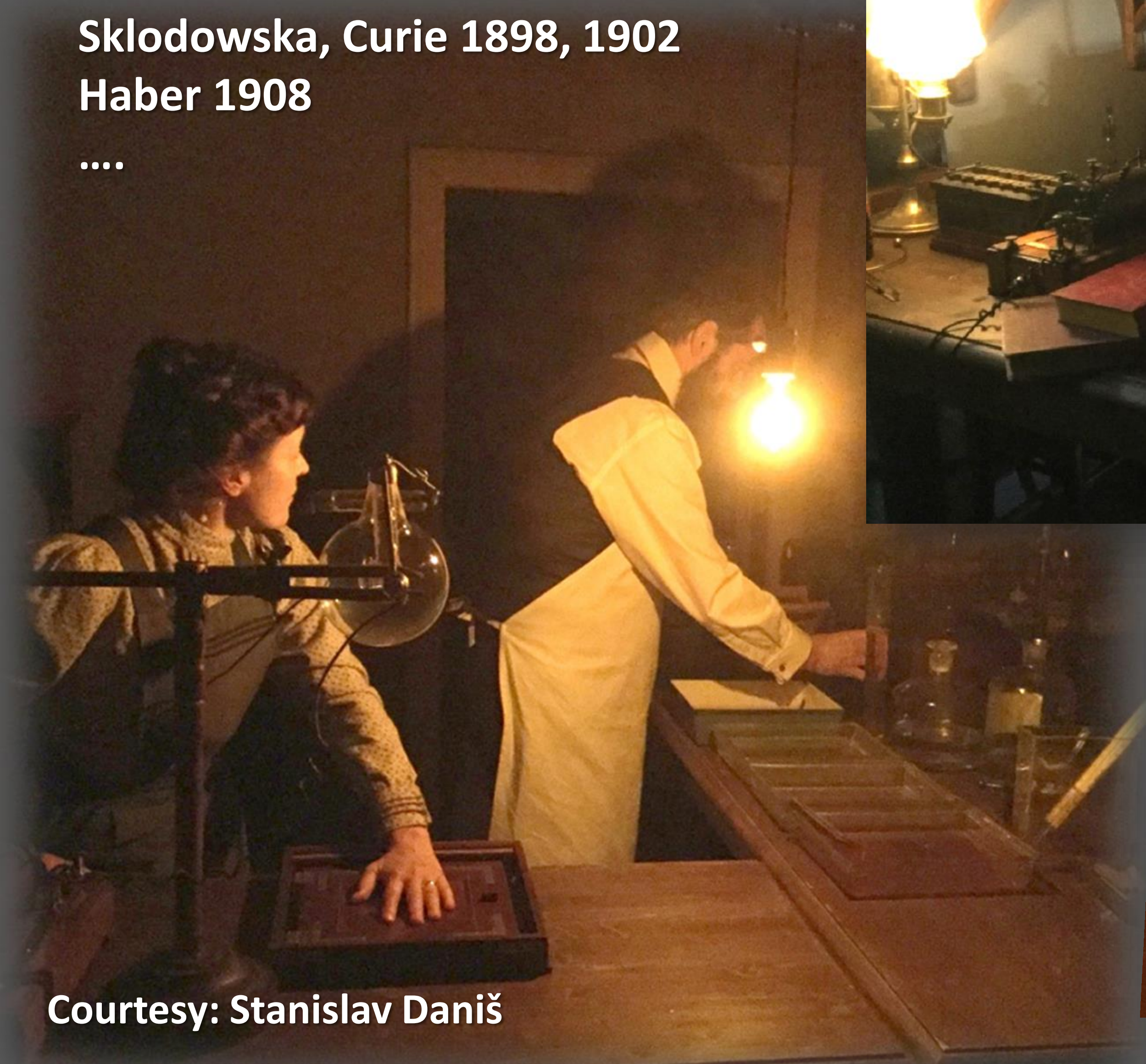
**Röntgen 1895**

**Lenard 1901**

**Sklodowska, Curie 1898, 1902**

**Haber 1908**

**....**



Courtesy: Stanislav Daniš

# Experiments, instruments, labs…

Röntgen 1895

Lenard 1901

Sklodowska, Curie 1898, 1902

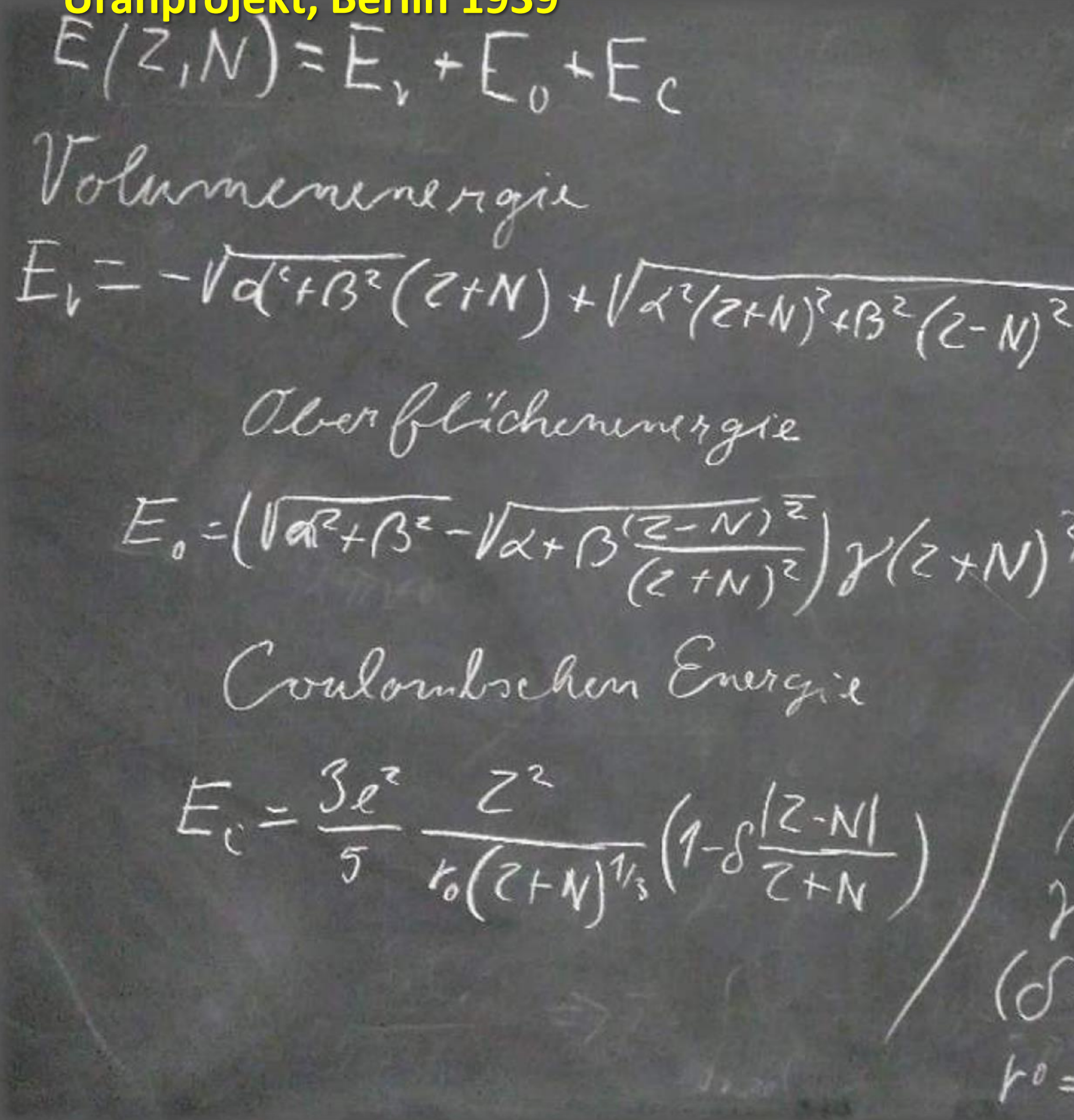
Haber 1908

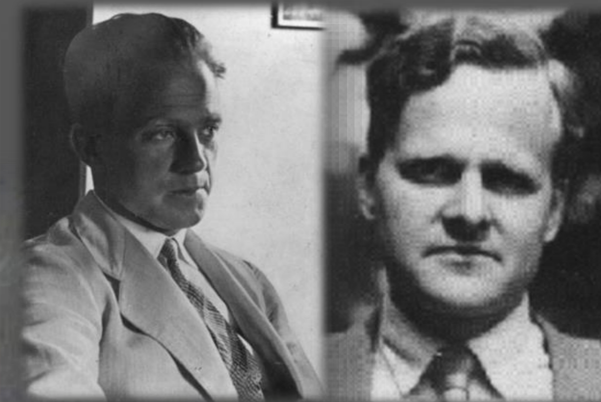
….

Courtesy: Stanislav Daniš

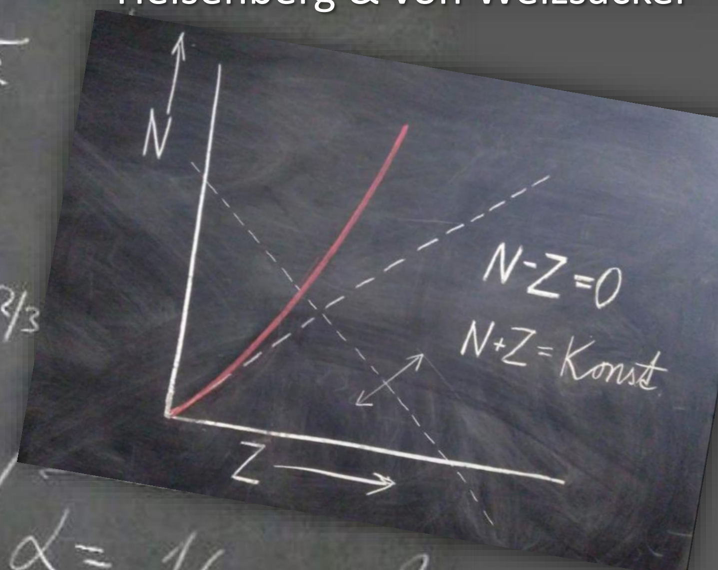
# Experiments, instruments, labs…

**Uranprojekt, Berlin 1939**



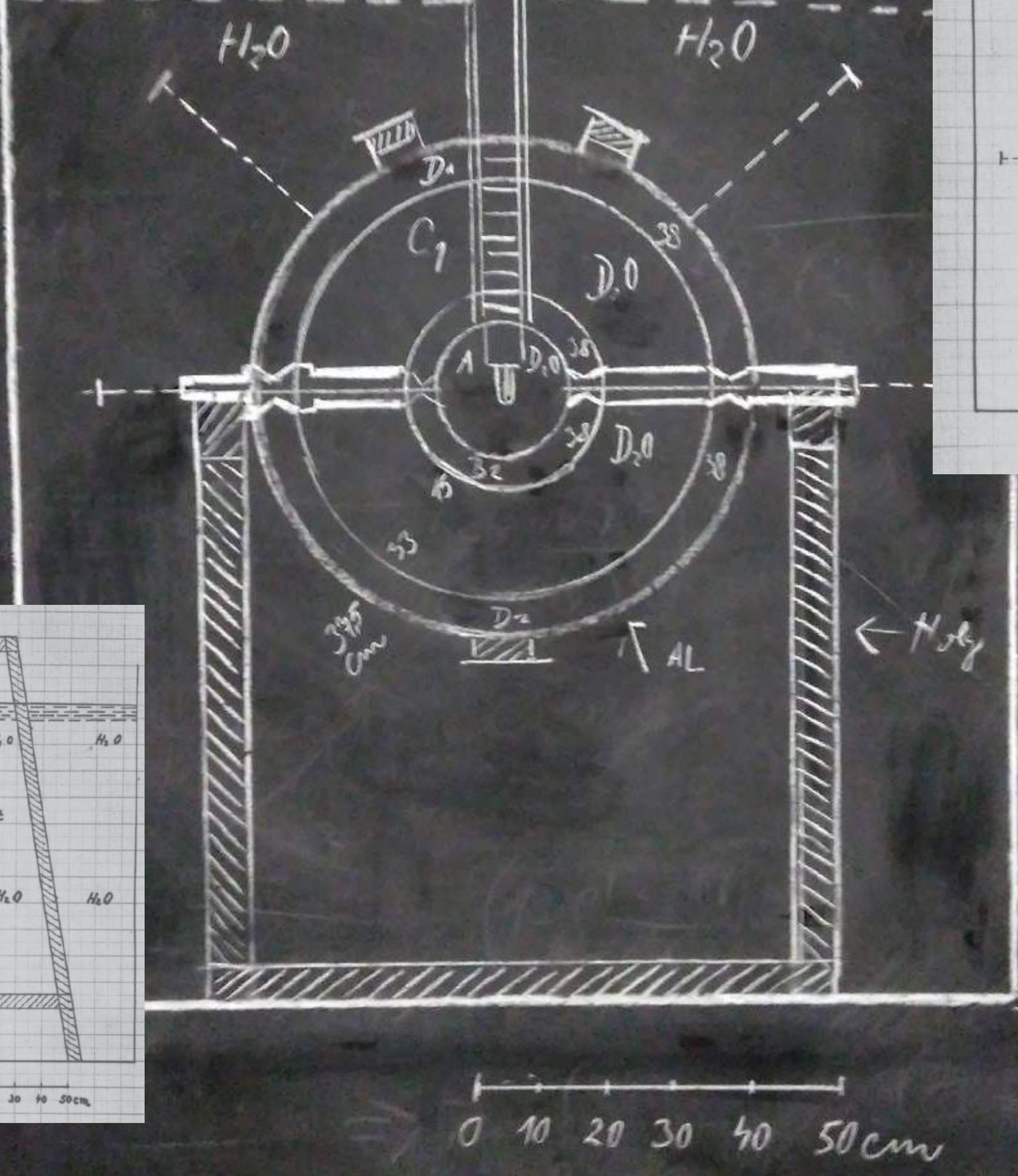



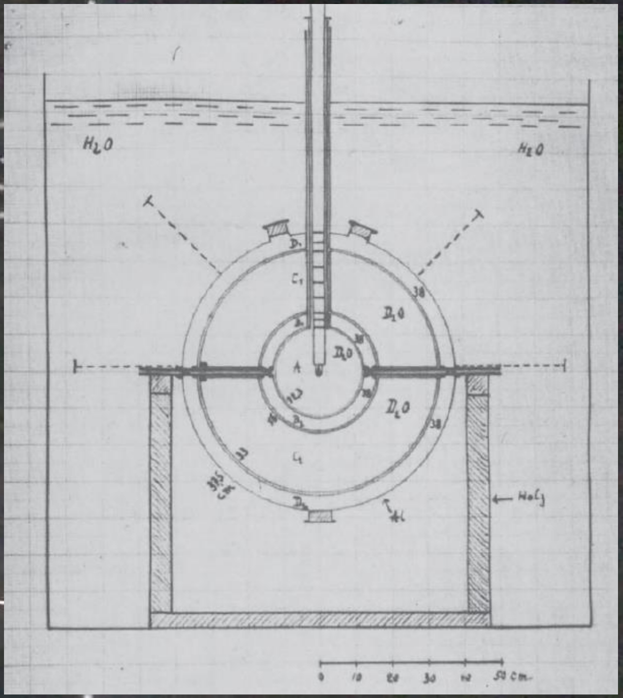
Heisenberg & von Weizsäcker

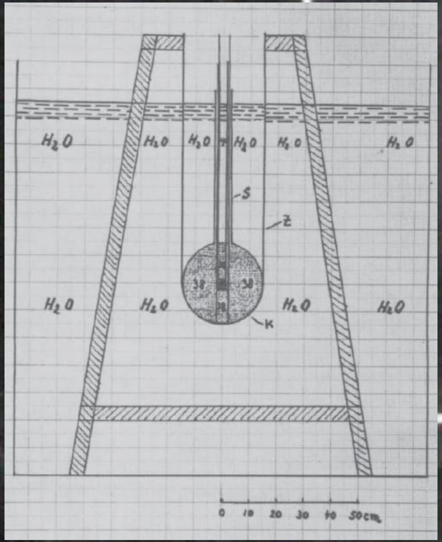


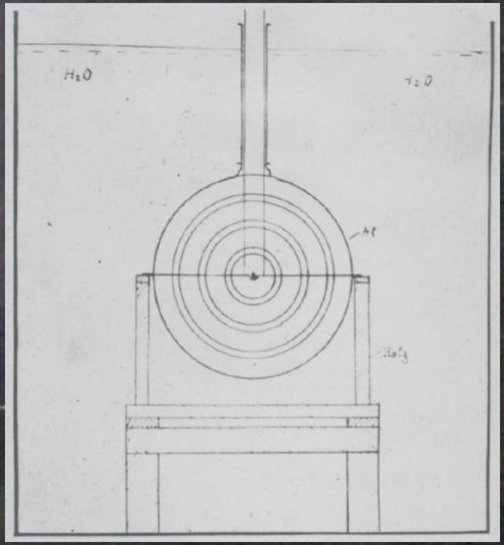
# Experiments, instruments, labs...

**Uranprojekt, Leipzig 1942**



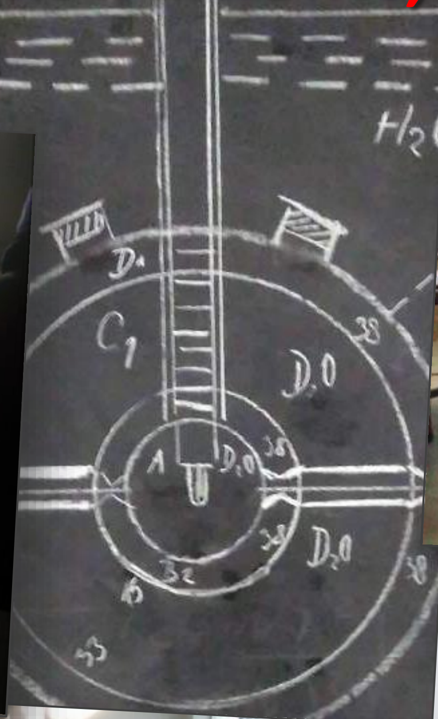



# Experiments, instruments, labs…

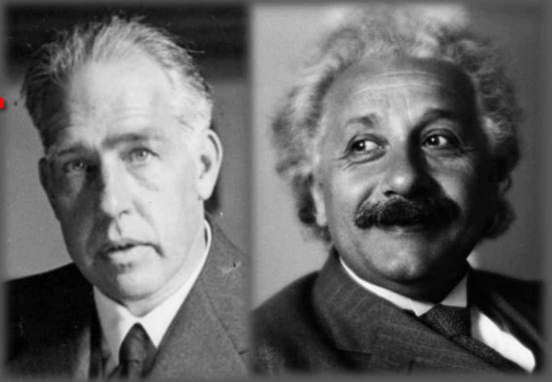
## Uranprojekt, Leipzig 1942

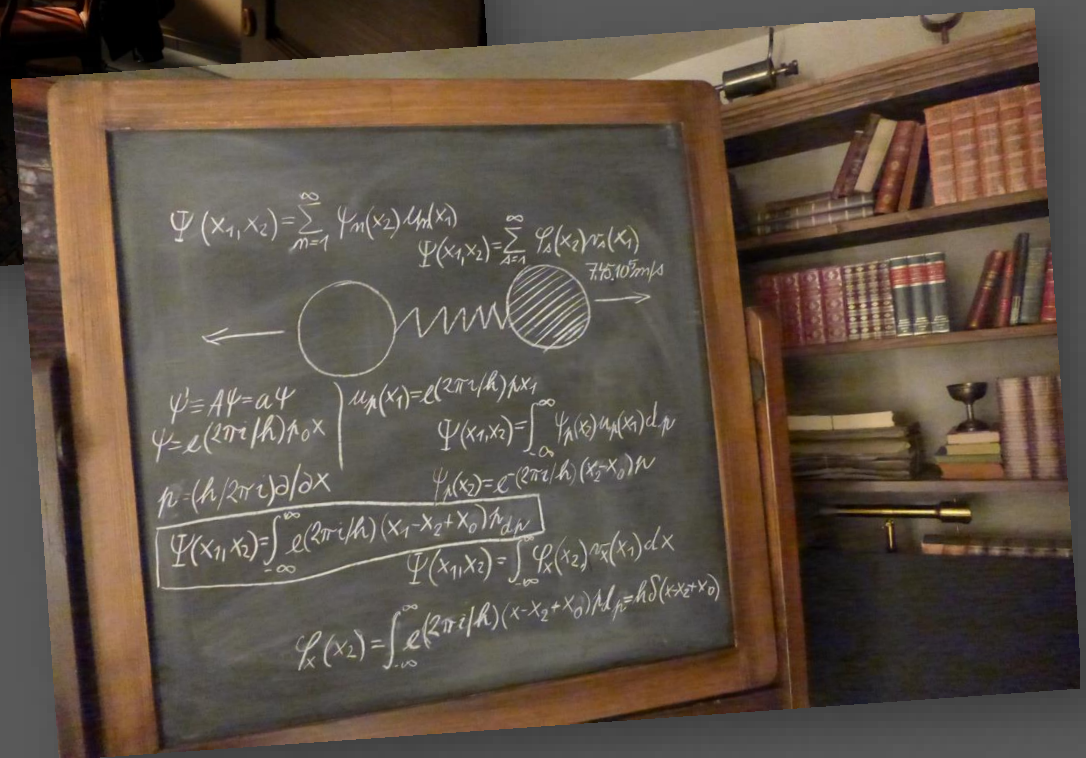




# Puzzles, trickinesses, brain-twisters…

**Einsten's home, Princeton <u>1935</u>**

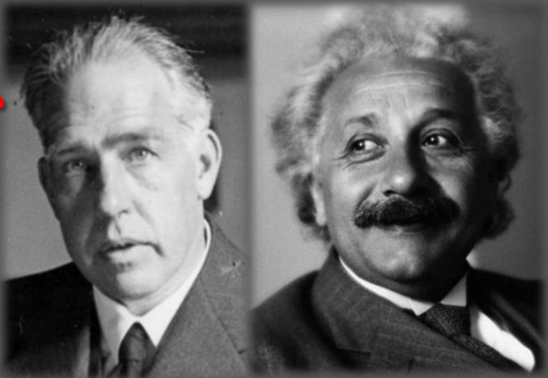


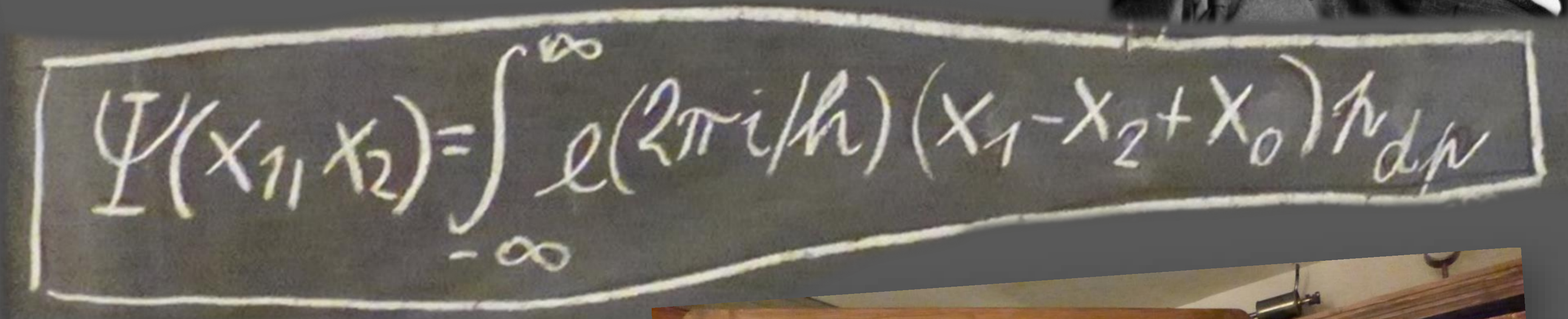


Einstein explains Bohr the **idea of the EPR paper** on incompleteness of quantum theory

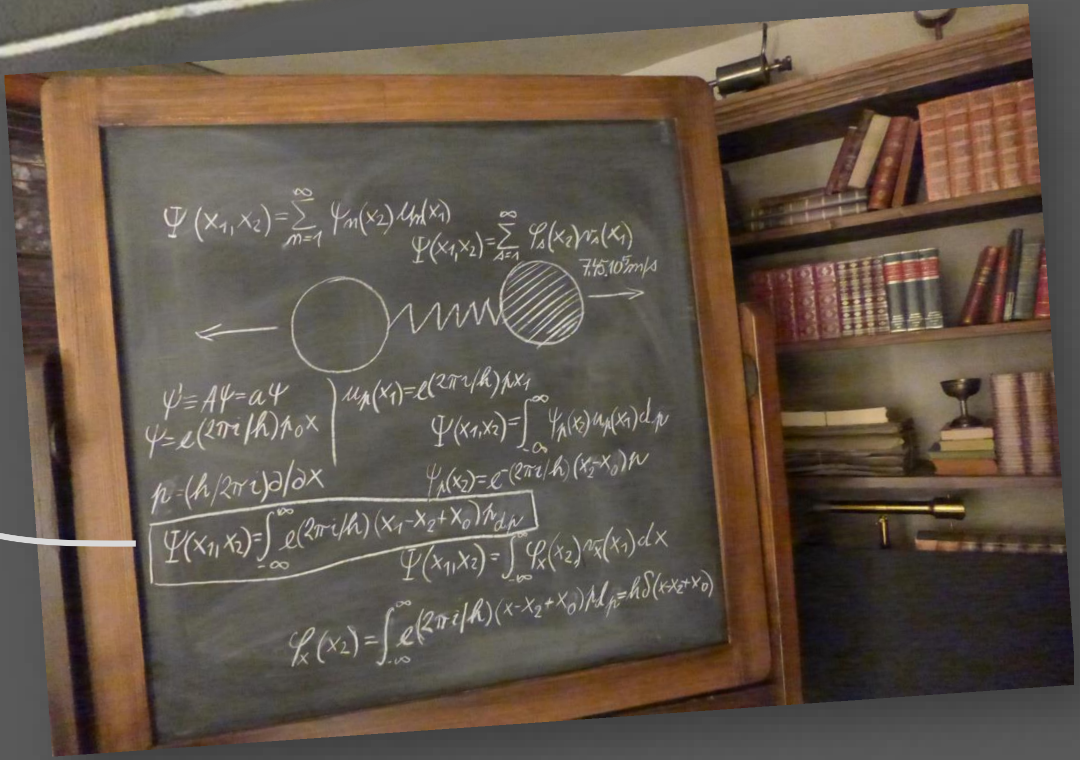
# Puzzles, trickinesses, brain-twisters…

**Einsten's home, Princeton 1935**



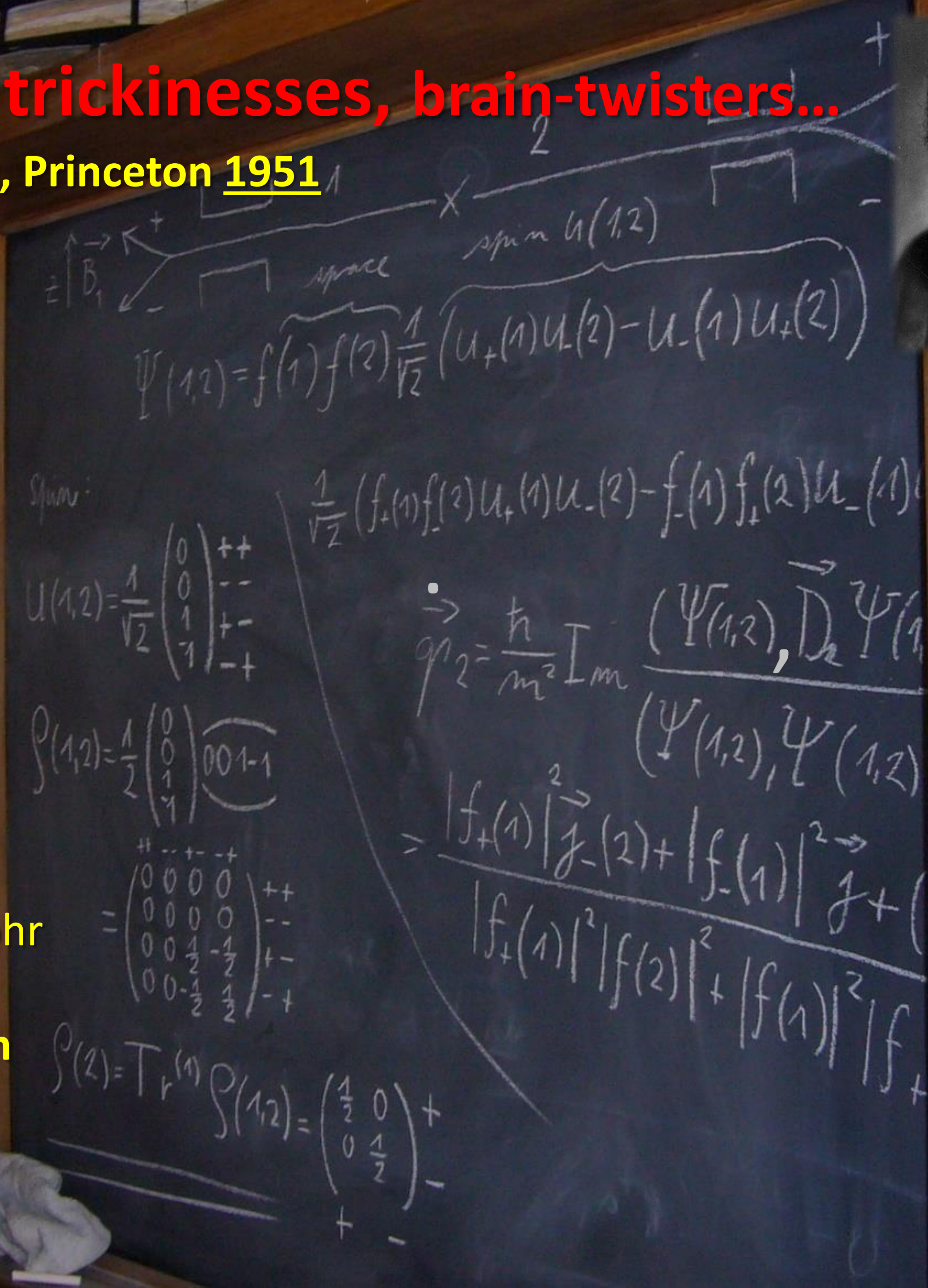


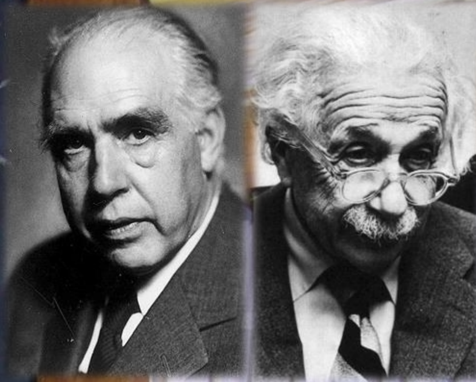

Einstein explains Bohr the **idea of the EPR paper** on incompleteness of quantum theory



# Puzzles, trickinesses, brain-twisters…

**Einsten's office, Princeton 1951**

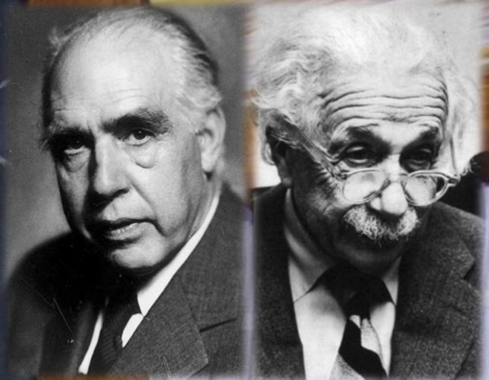




Einstein and Bohr have a **quarrel about quantum theory**

# Puzzles, trickinesses, brain-twisters…

**Einsten's office, Princeton 1951**



Spin formulation of EPR

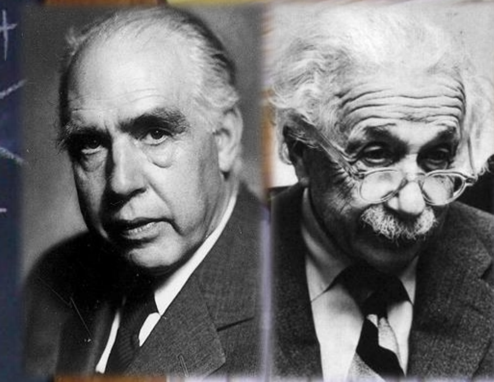
**Bohr**: Density matrix approach

**Einstein**: Bohmian interpretation

Einstein and Bohr have a **quarrel about quantum theory**

# Puzzles, trickinesses, brain-twisters…

## Einsten’s office, Princeton 1951

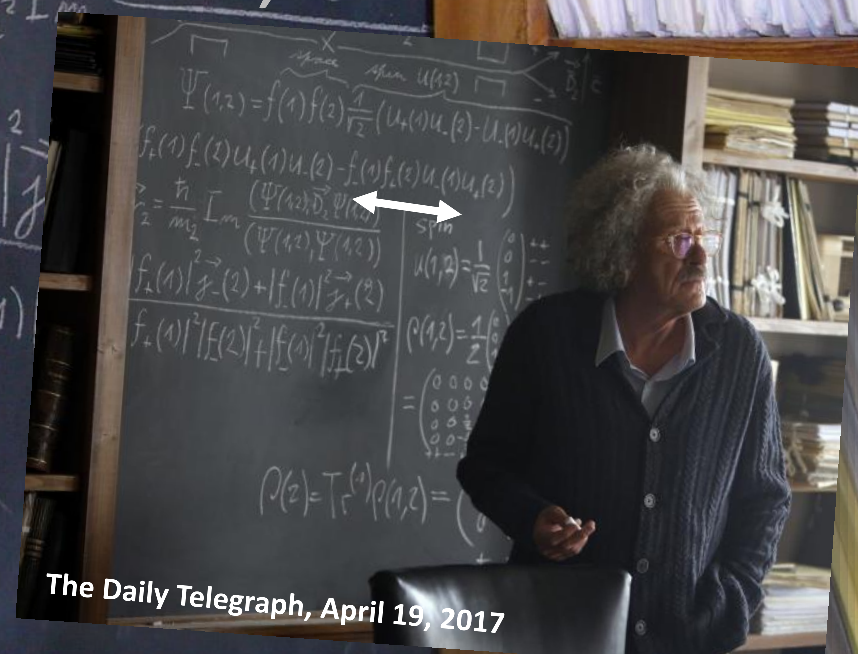


Spin formulation of EPR

**Bohr**: Density matrix approach

**Einstein**: Bohmian interpretation

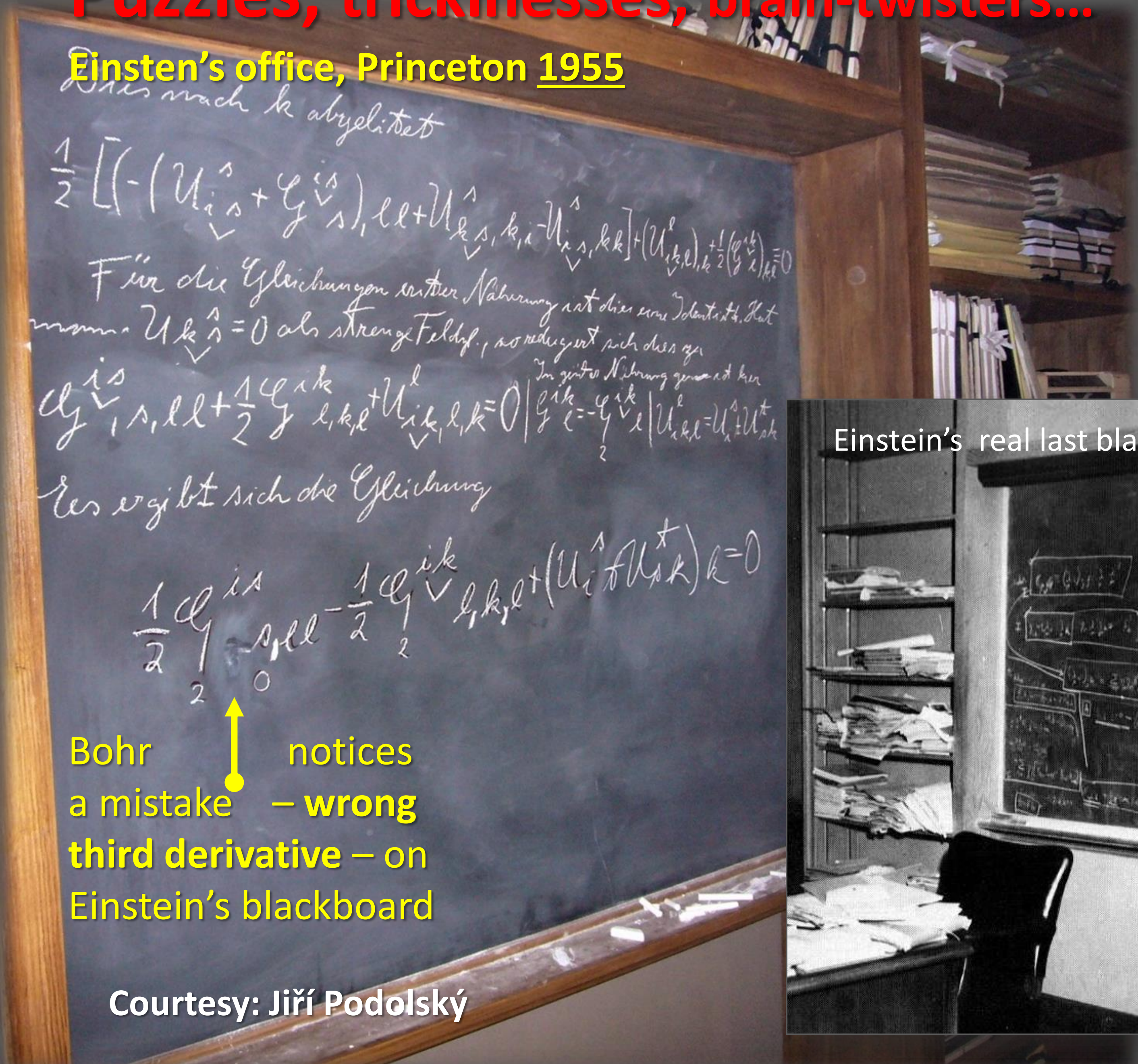
Einstein and Bohr have a **quarrel about quantum theory**



The Daily Telegraph, April 19, 2017

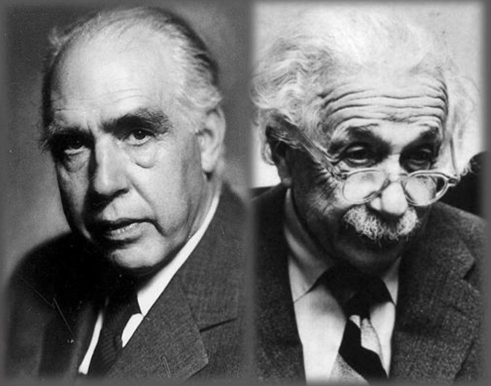
# Puzzles, trickinesses, brain-twisters…

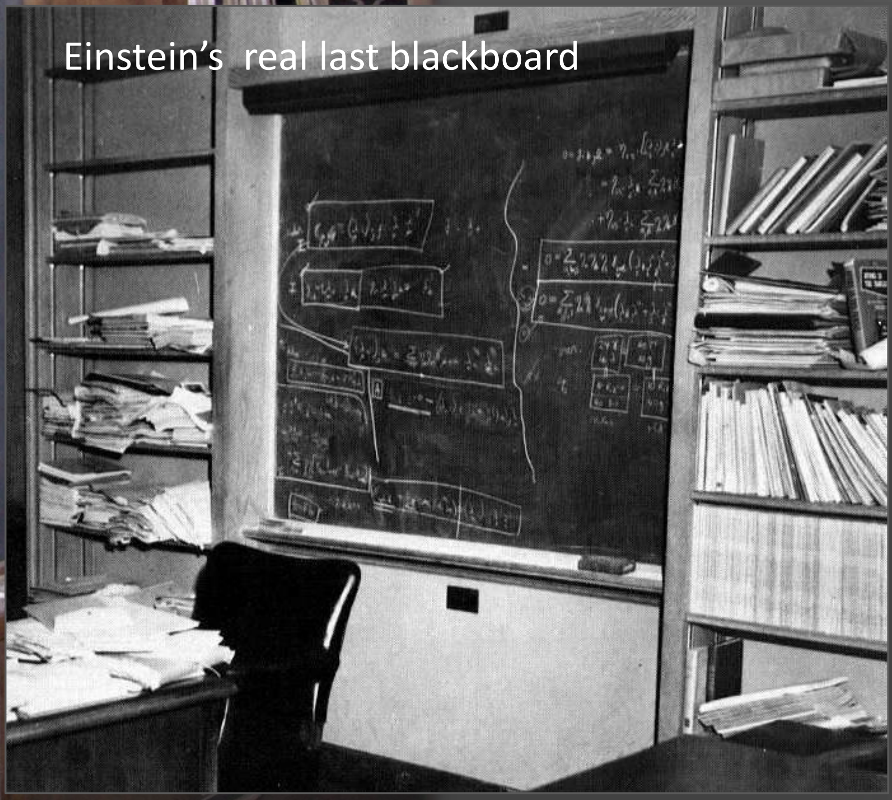
**Einsten's office, Princeton 1955**




Bohr notices a mistake – **wrong third derivative** – on Einstein's blackboard

**Courtesy: Jiří Podolský**

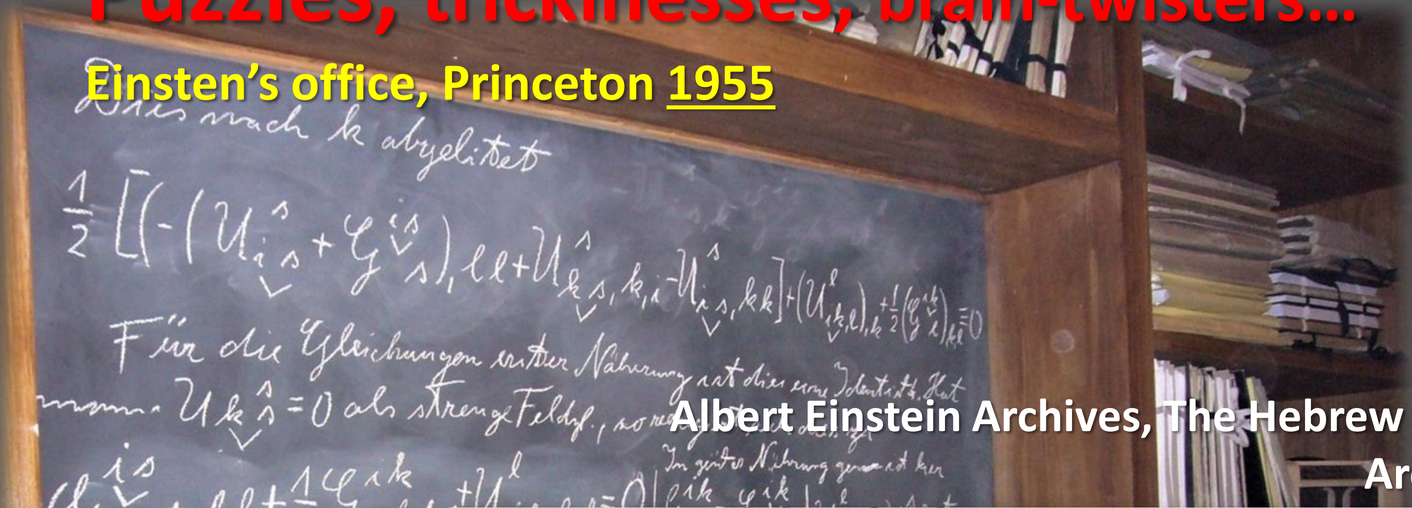


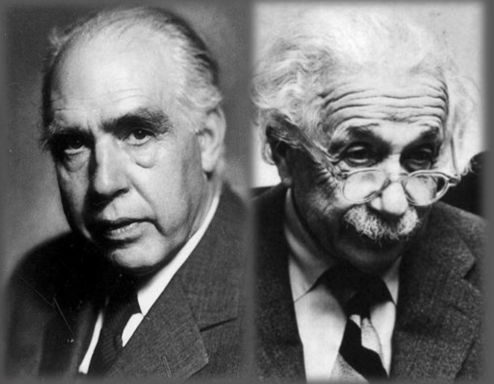


Einstein's real last blackboard

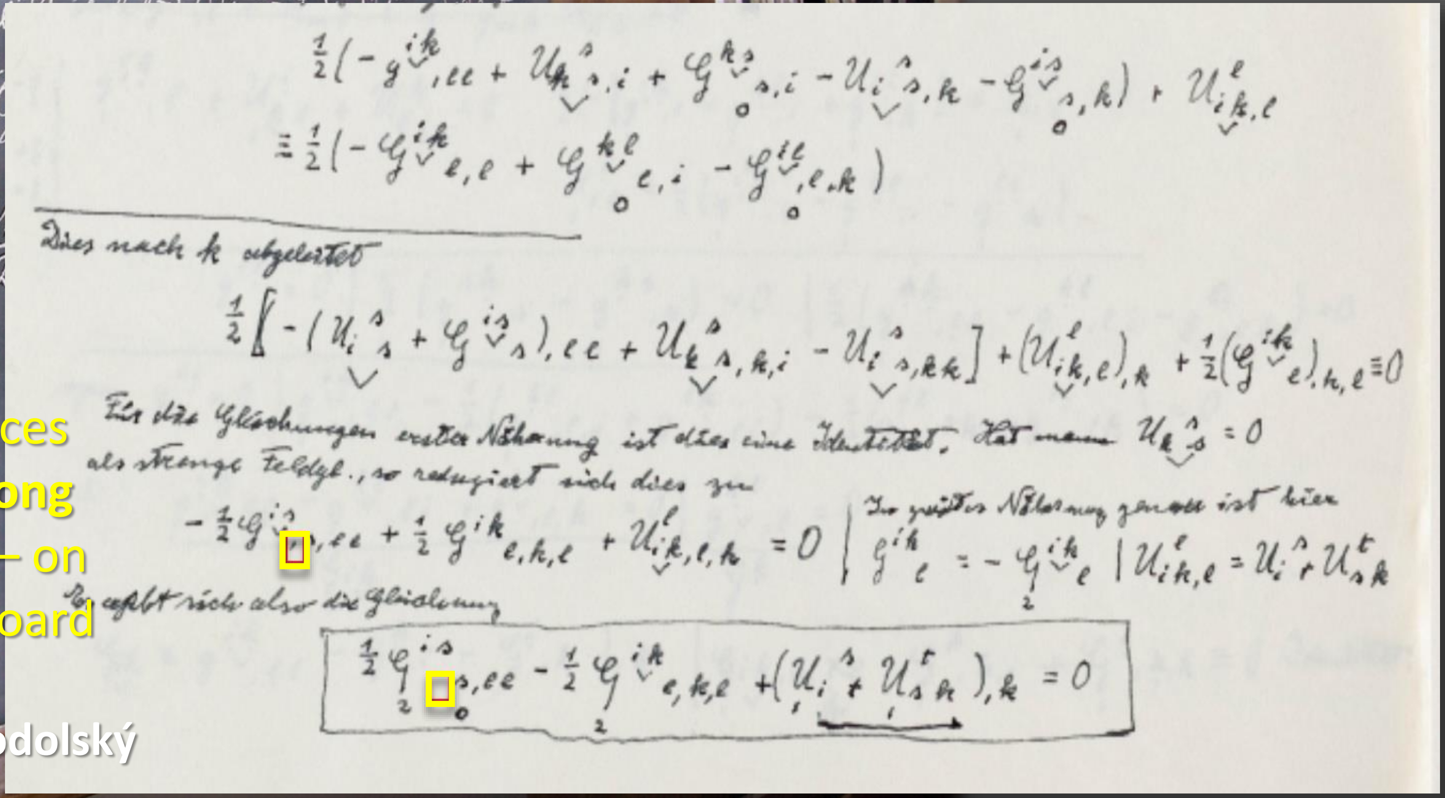
# Puzzles, trickinesses, brain-twisters…

**Einsten's office, Princeton 1955**



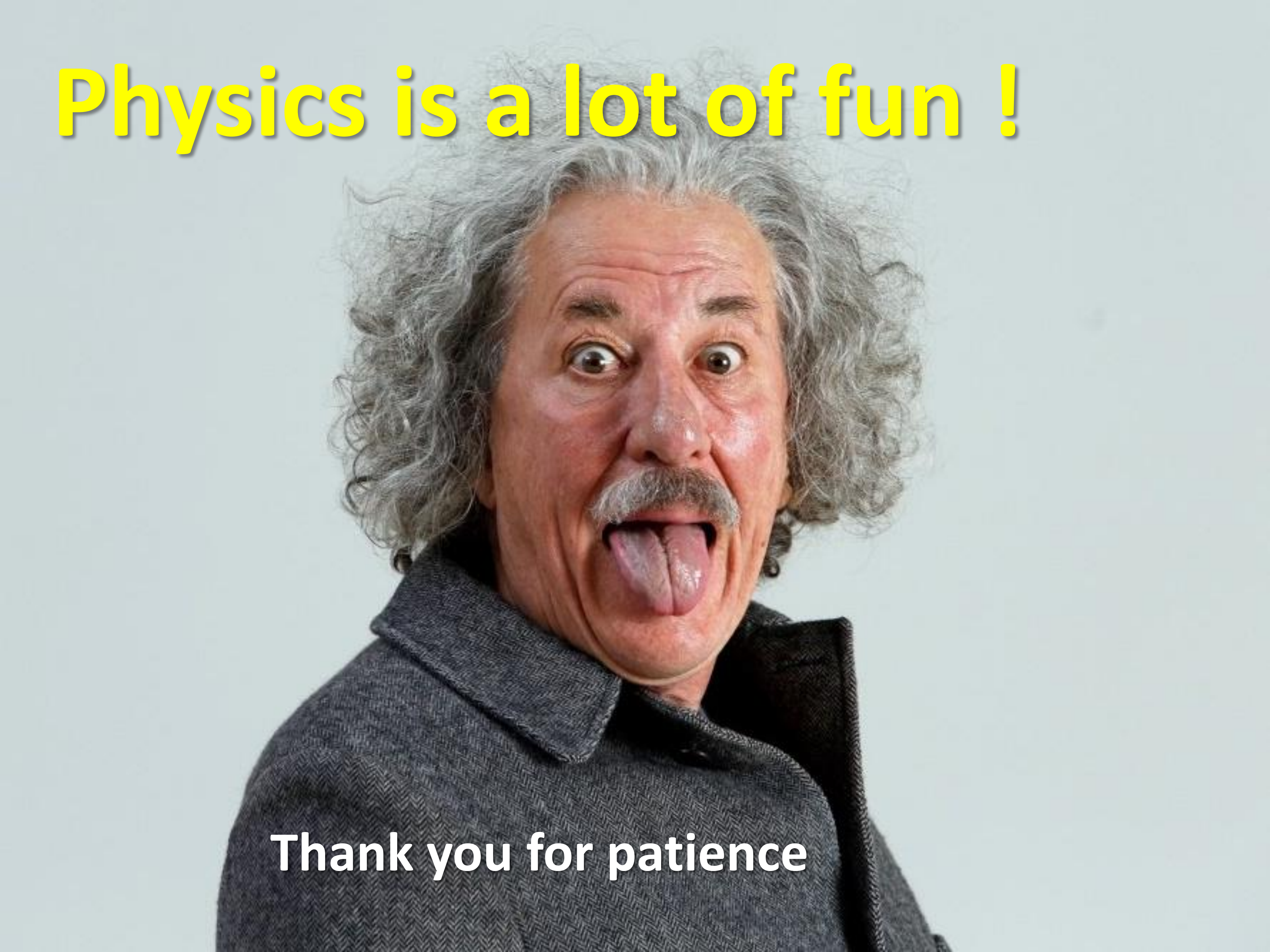


Albert Einstein Archives, The Hebrew University of Jerusalem
Archival Call Number 3-12




Bohr notices a mistake – **wrong third derivative** – on Einstein's blackboard

**Courtesy: Jiří Podolský**


Physics is a lot of fun !
Thank you for patience