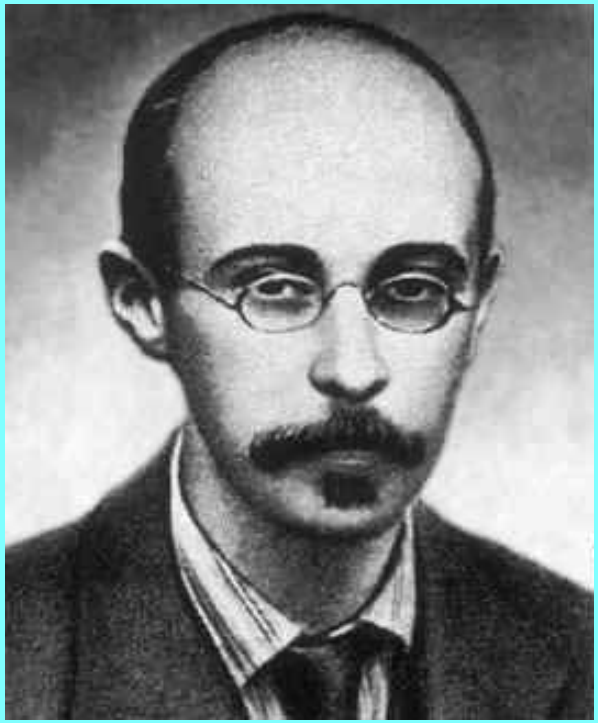
Albert Einstein and the Friedmann Equations

Albert Einstein



Alexander A. Friedmann

Publication of the Friedmann Equations

On the Curvature of Space

A. Friedmann
Petersburg
Received June 29, 1922
Zeitschrift für Physik

Einstein's Reaction

REMARK ON THE WORK OF A. FRIEDMANN (FRIEDMANN 1922)
"ON THE CURVATURE OF SPACE"
A. Einstein, Berlin
Received September 18, 1922
Zeitschrift für Physik

The work cited contains a result concerning a non-stationary world which seems suspect to me. Indeed, those solutions do not appear compatible with the field equations (A). From the field equations it follows necessarily that the divergence of the matter tensor T_{ik} vanishes. This along with the anzatzes (C) and (D) leads to the condition

$$\partial\rho/\partial x_4 = 0$$

which together with (8) implies that the world-radius R is constant in time. The significance of the work therefore is to demonstrate this constancy.

REFERENCES: Friedmann, A. 1922, *Zs. f. Phys.*, 10, 377.

Translation: *Cosmological Constants*, edited by Jeremy Bernstein and Gerald Feinberg

Sequence of Events

June 29, 1922: Friedmann's paper received at *Zeitschrift für Physik*.

September 18, 1922: Einstein's refutation received at *Zeitschrift für Physik*.

December 6, 1922: Friedmann learns about Einstein's objection from his friend, Yuri A. Krutkov, who is visiting in Berlin. Friedmann writes a detailed letter to Einstein. Einstein is traveling and does not read it.

May, 1923: Einstein meets Krutkov in Leiden, both attending the farewell lecture by Lorentz, who was retiring.

Krutkov's letters to his sister: "On Monday, May 7, 1923, I was reading, together with Einstein, Friedmann's article in the *Zeitschrift für Physik*." May 18: "I defeated Einstein in the argument about Friedmann. Petrograd's honor is saved!" *

May 31, 1923: Einstein's retraction of his refutation is received at *Zeitschrift für Physik*.

* Quoted in *Alexander A. Friedmann: the Man who Made the Universe Expand*, by E.A. Tropp, V. Ya. Frenkel, & A.D. Chernin.

Einstein's Retraction

A NOTE ON THE WORK OF A. FRIEDMANN
"ON THE CURVATURE OF SPACE"
A. Einstein, Berlin
Received May 31, 1923
Zeitschrift für Physik

I have in an earlier note (Einstein 1922) criticized the cited work (Friedmann 1922). My objection rested however — as Mr. Krutkoff in person and a letter from Mr. Friedmann convinced me — on a calculational error. I am convinced that Mr. Friedmann's results are both correct and clarifying. They show that in addition to the static solutions to the field equations there are time varying solutions with a spatially symmetric structure.

REFERENCES:

Einstein, A. 1922, *Zs. f. Phys.*, 11, 326.
Friedmann, A. 1922, *Ebenda,* 10, 377.

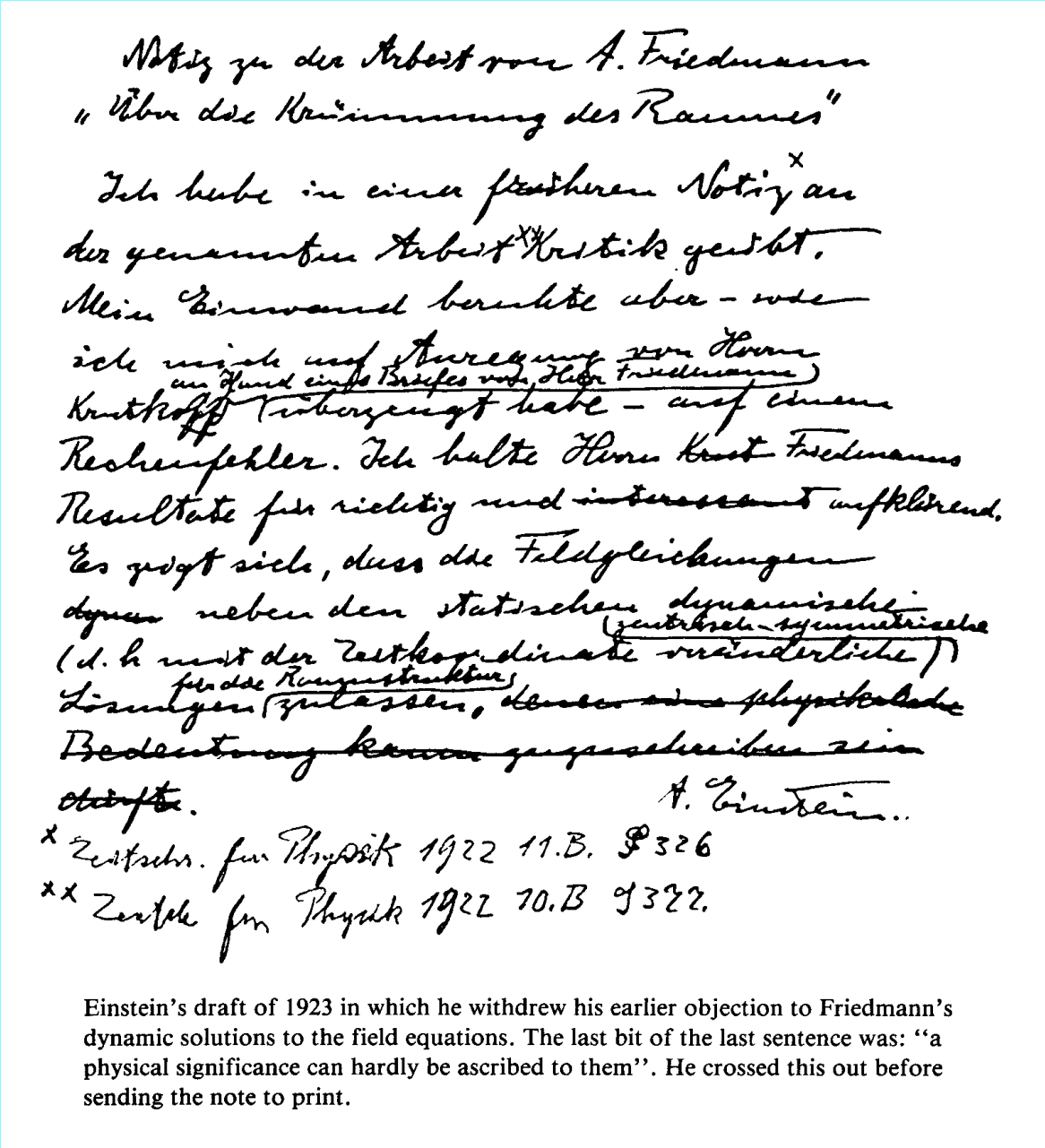
Translation: *Cosmological Constants*, edited by Jeremy Bernstein and Gerald Feinberg

Einstein and Krutkov

Albert Einstein
Barcelona, 1923

Yuri A. Krutkov.

Einstein's Draft



Notiz zu der Arbeit von A. Friedmann
„Über die Krümmung des Raumes"

Ich habe in einer früheren Notiz* an der genannten Arbeit** Kritik geübt. Mein Einwand beruhte aber – wie ich mich auf Anregung von Herrn Krutkoff (aus Anlass eines Briefes von Herrn Friedmann) überzeugt habe – auf einem Rechenfehler. Ich halte Herrn Friedmanns Resultate für richtig und ~~interessant~~ aufklärend. Es zeigt sich, dass die Feldgleichungen ~~dynam~~ neben den statischen dynamische (zeitlich-symmetrische) (d. h. mit der Zeitkoordinate veränderliche) Lösungen für die Raumstruktur zulassen, denen ~~eine physikalische Bedeutung kann zugeschrieben sein dürfte~~.

A. Einstein.

* Zeitschr. für Physik 1922 11.B. S 326

** Zeitschr. für Physik 1922 10.B S 377.

Einstein's draft of 1923 in which he withdrew his earlier objection to Friedmann's dynamic solutions to the field equations. The last bit of the last sentence was: "a physical significance can hardly be ascribed to them". He crossed this out before sending the note to print.

"a physical significance can hardly be ascribed to them."

* From *The Invented Universe*, by Pierre Kerszberg