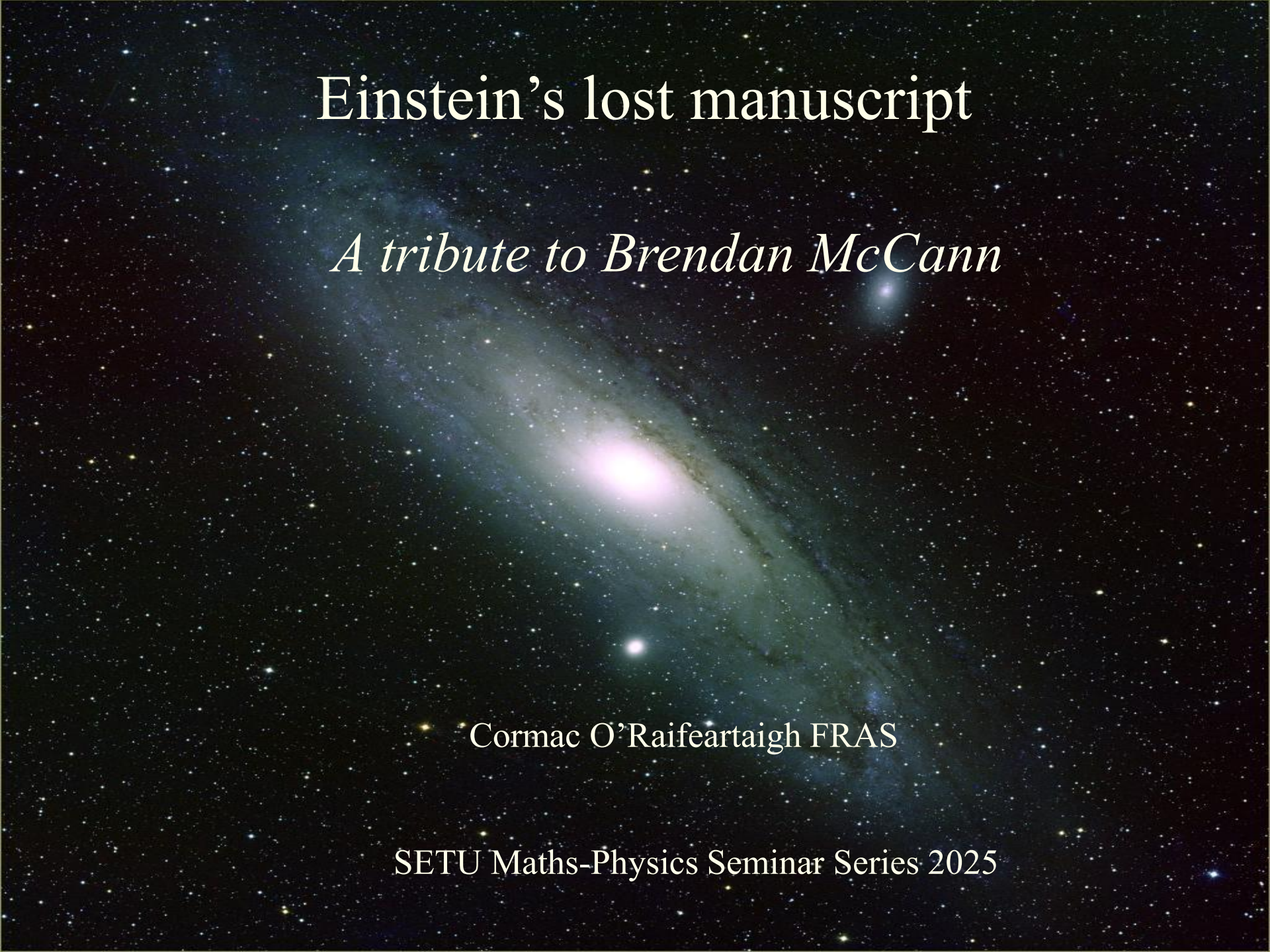
Einstein's lost manuscript

A tribute to Brendan McCann



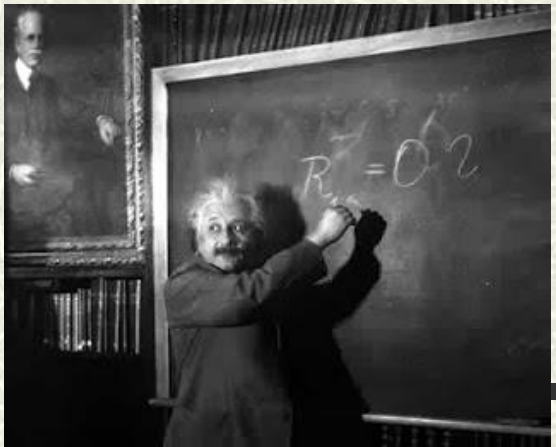
Cormac O'Raifeartaigh FRAS

SETU Maths-Physics Seminar Series 2025

Einstein's lost manuscript

- **An unpublished work**
  Written in early 1931
- **A 'steady-state' model of the universe**
  Expanding universe of constant density
  Anticipates controversial theory (Hoyle)
- **Fatal flaw**
  Quickly abandoned
- **Embraced evolving models**
  Friedman-Einstein model (1931)
  Einstein-de Sitter model (1932)

Einstein in California (1931)



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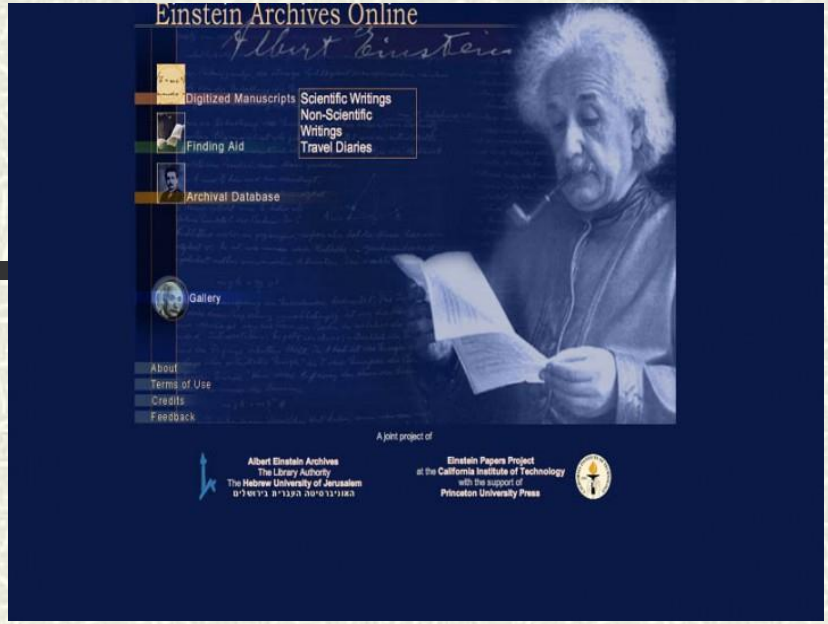


- **Albert Einstein Archive**

  Online archive of handwritten manuscripts

- **Manuscript misfiled**

  Misfiled as Einstein's 1931 model of the cosmos

  Hidden in plain sight

- **COR and BMC**

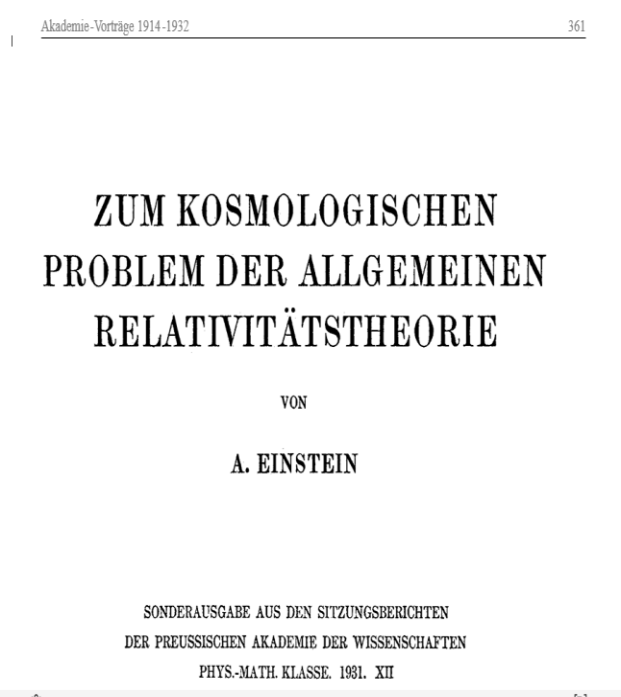
  Study and translation of Einstein's 1931 model

  Some anomalies in calculations

  BMC: Work from original manuscript?

- **A lucky discovery!**

  Archive MS something quite different – ss model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ZUM KOSMOLOGISCHEN PROBLEM DER ALLGEMEINEN RELATIVITÄTSTHEORIE

VON

A. EINSTEIN

SONDERAUSGABE AUS DEN SITZUNGSBERICHTEN
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Einstein's lost theory uncovered

Physicist explored the idea of a steady-state Universe in 1931.

Davide Castelvecchi

24 February 2014

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Einstein's Lost Theory Uncovered

The famous physicist explored the idea of a steady-state universe in 1931

nature

Feb 25, 2014 | By Davide Castelvecchi and Nature magazine

A manuscript that lay unnoticed by scientists for decades has revealed that Albert Einstein once dabbled with an

New Discovery Reveals Einstein Tried To Devise A Steady State Model Of The Universe

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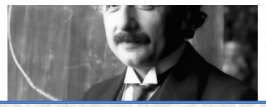

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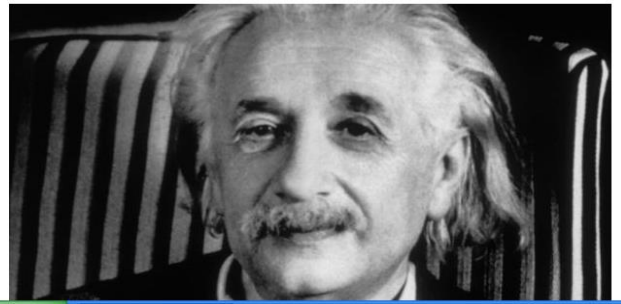
News / Science

WIT researchers discover 'lost' Einstein model of universe

Scientists uncovered misfiled papers while searching Jerusalem university's online archive



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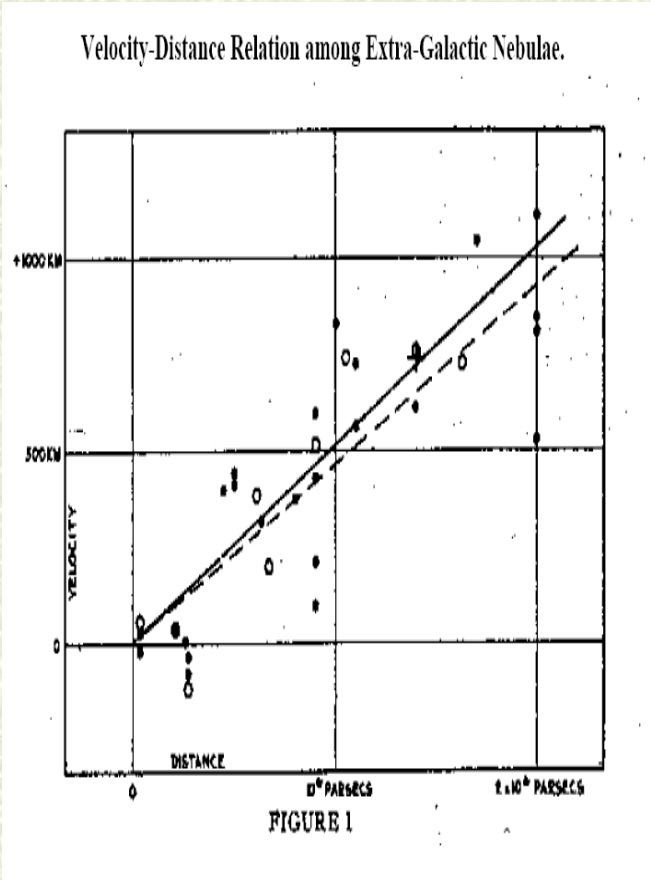
Scientific context

- **Hubble's law (1929)**
  Linear relation between redshift and distance
- **Crisis for cosmology**
  What is causing the galaxies to move?
- **Expansion of space?**
  Predicted by general relativity
- **Friedman-Lemaitre models**
  Friedman's expanding universe (1922)
  Lemaitre's expanding universe (1927)



Introduction to general relativity

- **Space+time = space-time**

  Spacetime dynamic (1905)

- **Spacetime distorted by mass**

  Distortion causes other mass to move (1915)

Albert Einstein

Gravity = curvature of space-time

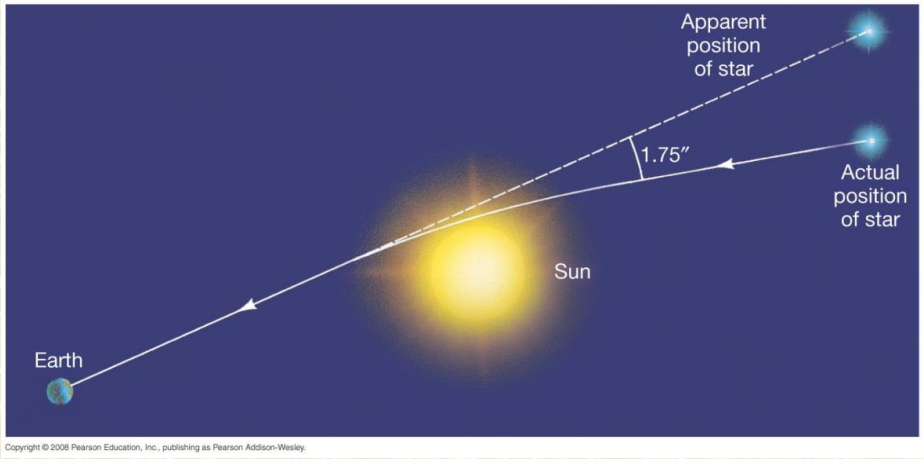
$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

- **Dyson/Eddington expeditions (1919)**

  Measure bending of light?

  Successful result

  General relativity well-known

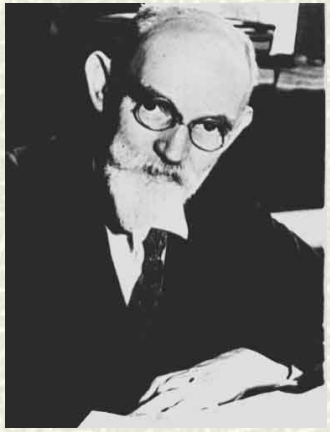


Relativity and the universe

Einstein model (1917)

- Assume static universe
- Add cosmic constant term to give static solution
- Closed curvature, finite radius

$$G_{\mu\nu} + \lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$



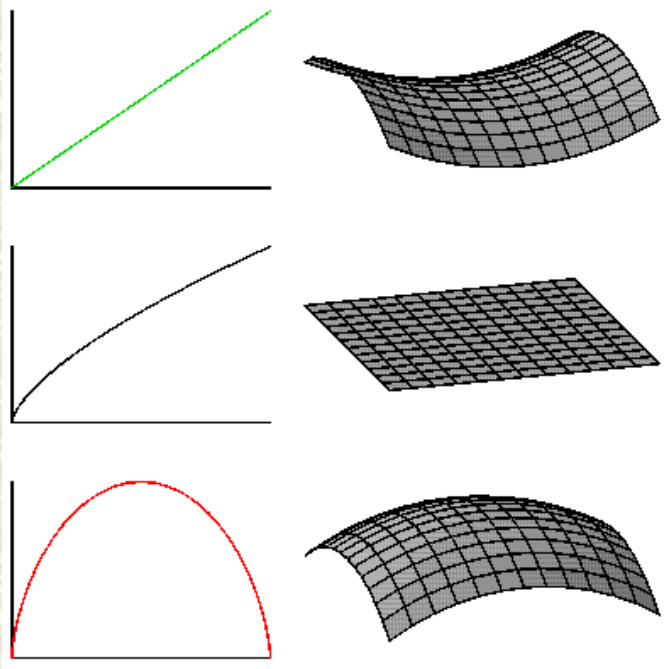
De Sitter (1917)

- Empty universe
- Apparently static (co-ordinate system)
- Prediction of redshifts

Friedman models of the cosmos

Alexander Friedman 1888 -1925

- **Allow time-varying solutions to the field equations**
  Expanding, contracting universes
- **Geometry, evolution depends on matter content**
  Positive curvature (1922)
  Hyperbolic curvature (1924)
- **Mathematical models (Zf. Ph.)**
  To be decided by astronomy
- **Ignored by community**
  Disliked by Einstein
  Correction and retraction



Lemaître's universe (1927)

Fr Georges Lemaître

- **Time-varying solutions to the field equations**

  Expanding universe?

- **Redshifts of galaxies = expansion of space***?*

  Rate of expansion from mean distances and redshifts

  H = 585 km/s/Mpc (1927)

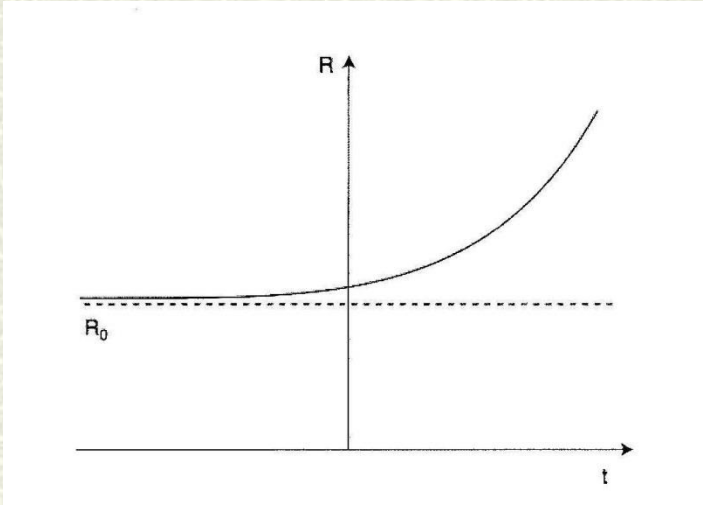
- **Rejected by Einstein**

  "Votre physique est abominable"

  Ditto for Friedman

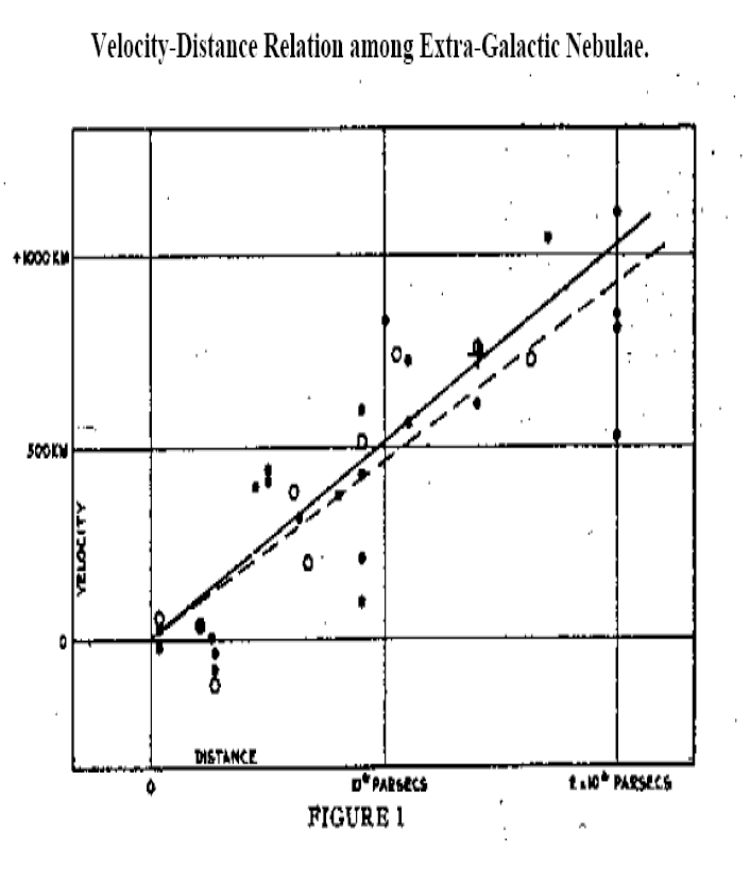
- **No beginning: indefinite age**

  Starts from Einstein universe at t = - ∞



The paradigm shift

- **Hubble's law (1929)**
  Linear relation between redshift and distance
- **RAS meeting (1930)**
  Einstein/de Sitter models don't fit data
  New model required
- **Hubble's law = cosmic expansion?**
  If redshifts are velocities (Zwicky)
  If effect is non-local
- **Letter from Lemaître**
  Recalls his 1927 model
  Eddington, de Sitter impressed



Cosmic expansion?

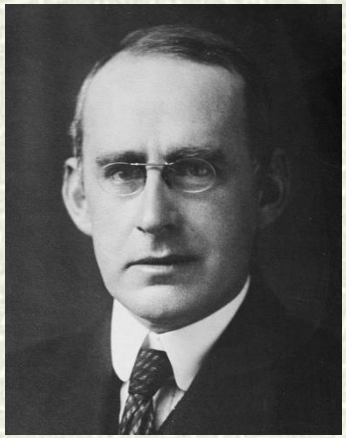
The expanding, evolving universe (1930 -32)

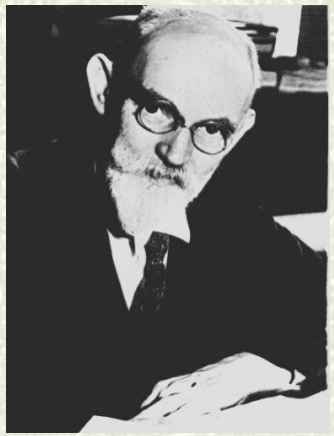
- **Eddington (1930, 31)**
  On the instability of the Einstein universe
  Expansion caused by condensation?
  The Eddington-Lemaître model

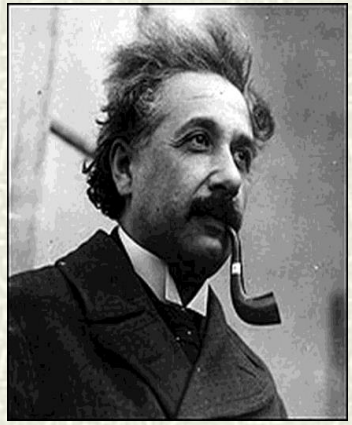
- **de Sitter (1930, 31)**
  Further remarks on the expanding universe
  Expanding universes of every flavour

- **Tolman (1930, 31)**
  On the behaviour of non-static models
  Expansion caused by annihilation of matter ?

- **Einstein (1931, 32)**
  Friedman-Einstein model $\lambda = 0, k = 1$
  Einstein-deSitter model $\lambda = 0, k = 0$



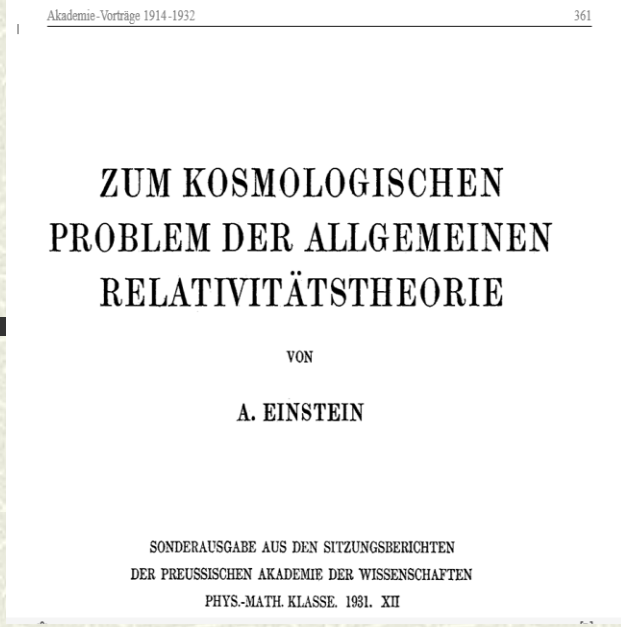




Evolving models

Einstein's 1931 model (*F-E*)

- **Hubble's observations**
  Expanding cosmos
- **Adopts Friedman 1922 analysis**
  Set cosmic constant $\lambda = 0$
- **Extract parameters**
  Density of matter: $\rho \sim 10^{-26}$ g/cm^3
  Size of universe: $P \sim 10^8$ light-years
  Some numerical inconsistencies
- **Translation and analysis?**
  Brendan McCann – use original MS?
  COR – use Oxford blackboard instead



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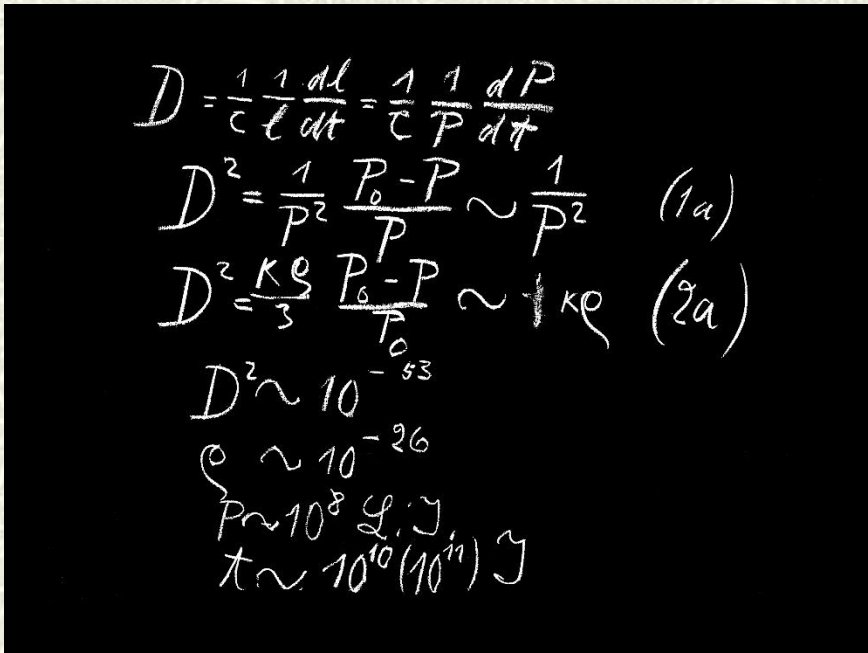
DER PREUSSISCHEN AKADEMIE DER WISSENSCHAFTEN
PHYS.-MATH. KLASSE. 1931. XII

Friedman-Einstein universe



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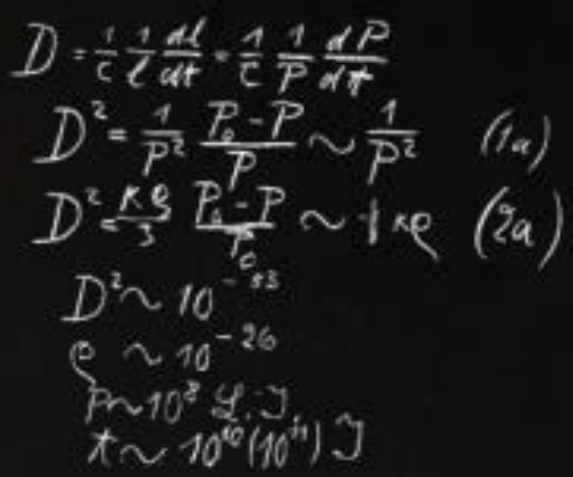


An image of the blackboard used in Einstein's 2nd Rhodes lecture at Oxford in April 1931 (reproduced by permission of the Museum of the History of Science, University of Oxford)

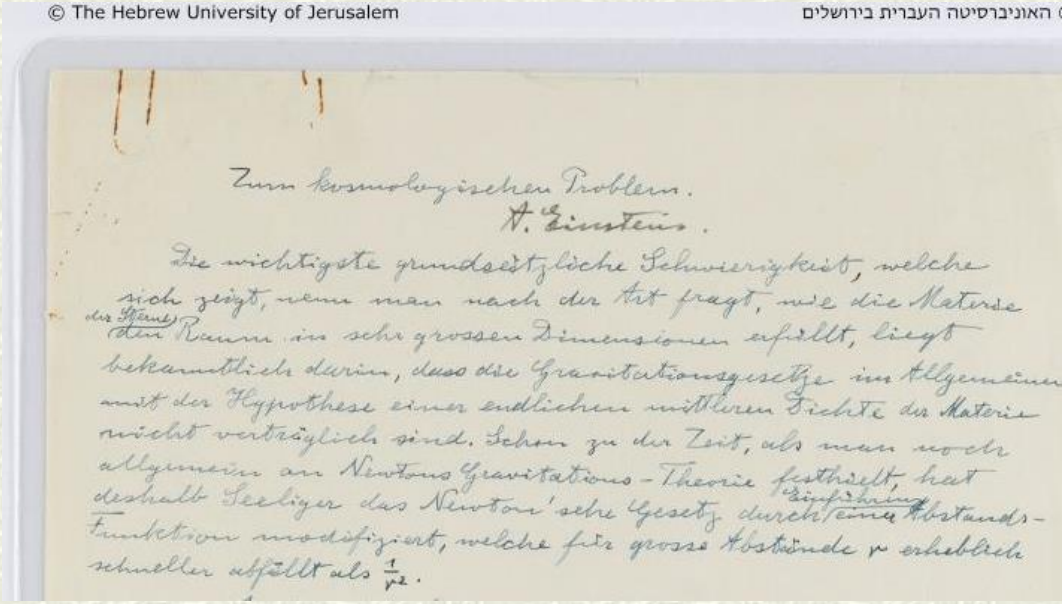
Einstein's cosmic model of 1931 revisited: An analysis and translation of a forgotten model of the universe

by Cormac O'Raifeartaigh and Brendan McCann

edp sciences Springer

Surprise: Einstein's steady-state model

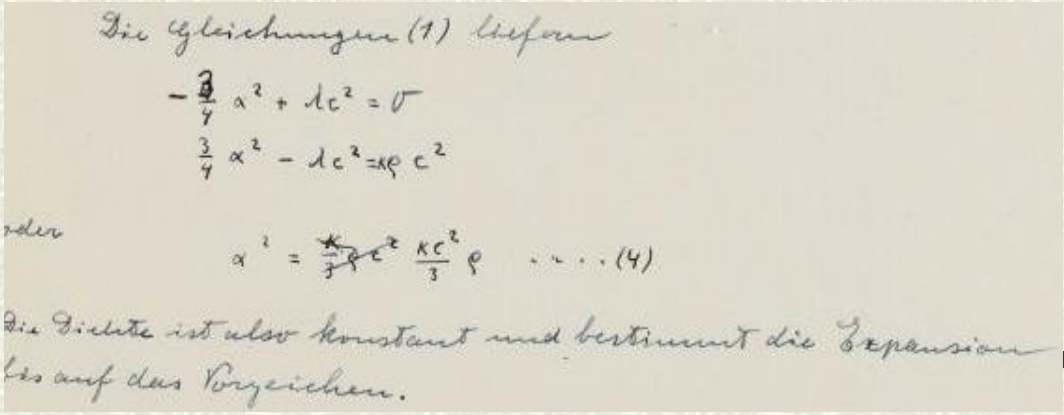
- **Filed as draft of 1931 F-E model**
  Similar title, opening
- **Cites Hubble's law**
  Cosmic expansion?
- **Cites evolving models (Tolman)**
  Discusses age problem
- **<u>Proposes alternative solution</u>**
  Constant density
  Determines the expansion



Zum kosmologischen Problem.

A. Einstein.

Die wichtigste grundsätzliche Schwierigkeit, welche sich zeigt, wenn man nach der Art fragt, wie die Materie den Raum in sehr grossen Dimensionen erfüllt, liegt bekanntlich darin, dass die Gravitationsgesetze im Allgemeinen mit der Hypothese einer endlichen mittleren Dichte der Materie nicht verträglich sind. Schon zu der Zeit, als man noch allgemein an Newtons Gravitations-Theorie festhielt, hat deshalb Seeliger das Newton'sche Gesetz durch eine Abstands-Funktion modifiziert, welche für grosse Abstände r erheblich schneller abfällt als $\frac{1}{r^2}$.



Die Gleichungen (1) liefern

$$-\frac{3}{4}\alpha^2 + \lambda c^2 = 0$$

$$\frac{3}{4}\alpha^2 - \lambda c^2 = \kappa \rho c^2$$

oder

$$\alpha^2 = \frac{\kappa c^2}{3}\rho \quad \ldots\ldots (4)$$

Die Dichte ist also konstant und bestimmt die Expansion bis auf das Vorzeichen.

Einstein's steady-state model: key quotes

Transl. BMC

New solution

"In what follows, I wish to draw attention to a solution to equation (1) that can account for Hubbel's facts, and in which the density is constant over time"

Matter creation

"If one considers a physically bounded volume, particles of matter will be continually leaving it. For the density to remain constant, new particles of matter must be continually formed within that volume from space "

Dark energy

"The conservation law is preserved in that, by setting the λ-term, space itself is not empty of energy; its validity is well known to be guaranteed by equations (1)."

Why was the model not published?

- **Model fails**
  De Sitter metric
  No creation term in GFE

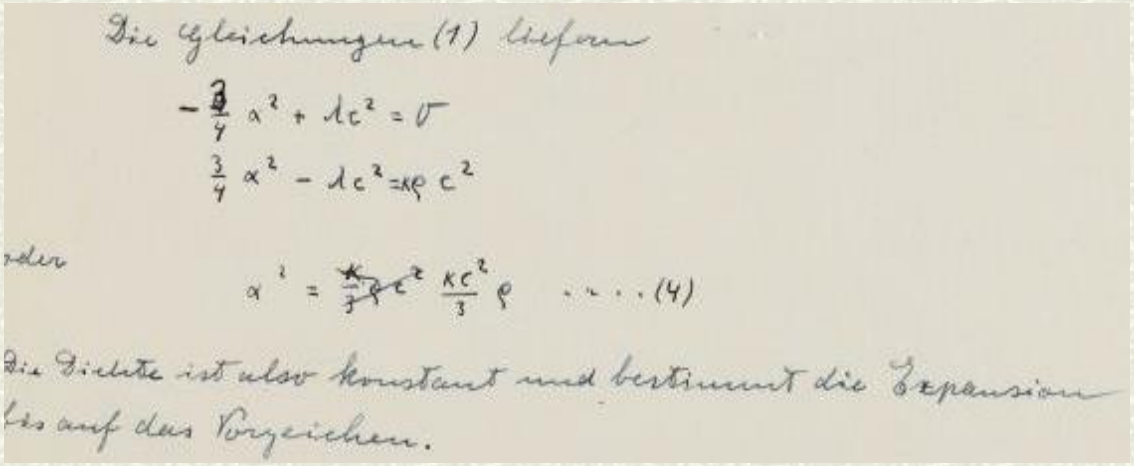
- **Null solution masked by error**
  Error in Christoffel coefficient
  9/4 instead of -3/4

- **Einstein's crossroads**
  Realised problem on revision
  Declined to alter GFE

- **Switched to evolving models**
  Less contrived and set $\lambda = 0$

Werner Nahm

Simon Mitton



Einstein's steady-state theory: an abandoned model of the cosmos

Published: 20 June 2014

Volume 39, pages 353–367, (2014) Cite this article

The European Physical Journal H

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Cormac O'Raifeartaigh, Brendan McCann, Werner Nahm & Simon Mitton

Abstract

We present a translation and analysis of an unpublished manuscript by Albert Einstein in which he attempted to construct a 'steady-state' model of the universe. The manuscript, which appears to have been written in early 1931, demonstrates that Einstein once explored a cosmic model in which the mean density of matter in an expanding universe is maintained constant by the continuous formation of matter from empty space. This model is very different to previously known Einsteinian models of the cosmos (both static and dynamic) but anticipates the later steady-state cosmology of Hoyle, Bondi and Gold in some ways. We find that Einstein's steady-state model contains a fundamental flaw and suggest that it was abandoned for this reason. We also suggest that he declined to explore a more sophisticated version because he found such theories rather contrived. The manuscript is of historical interest because it reveals that Einstein debated between steady-state and evolving models of the cosmos decades before a similar debate took place in the cosmological community.

The steady-state universe (1948)

- **Expanding but unchanging universe**

  Hoyle, Bondi and Gold (1948)

  No beginning, no age paradox

  No assumptions about physics of early epochs

Bondi, Gold and Hoyle

- **Continuous creation of matter**

  Very little matter required

- **Replace λ with creation term** (Hoyle)

$$G_{\mu\nu} + C_{\mu\nu} = k\,T_{\mu\nu}$$

Conservation of energy violated

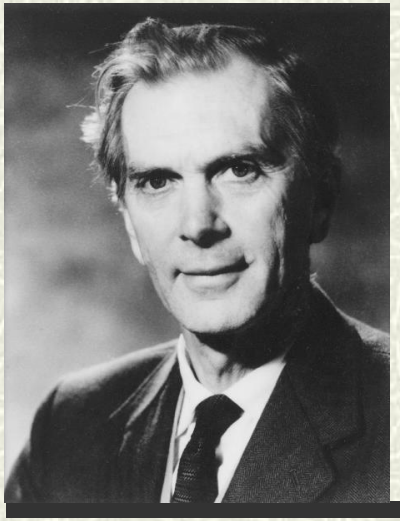
Hoyle and Narlikar (1962)

- **Improved version (1962)**

$$G_{\mu\nu} + \lambda g_{\mu\nu} = k\,T\,(C_{\mu} + C_{\nu})$$

A bitter debate (1950-1965)

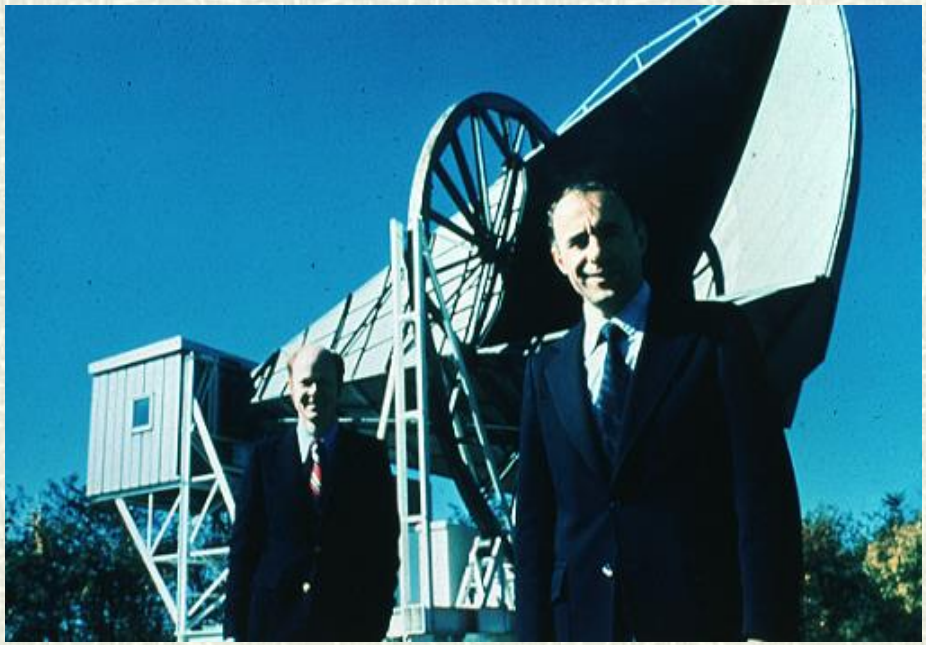
- **Steady-State or Big Bang universe?**
  Unchanging or evolving universe?
- **Study most distant galaxies**
  Compare with local galaxies
  Galaxy distribution over time?
- **Radio-astronomy (Ryle)**
  Cambridge 3C Survey: evolving universe
- **Developments in optical astronomy**
  Timescale of expansion (Baade)



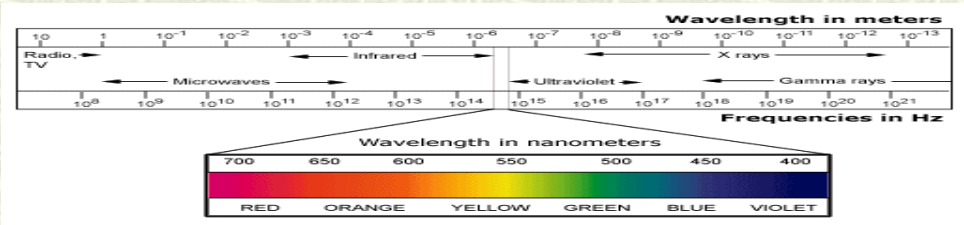
Cosmic microwave background (1965)

- **Radio receivers (AT&T)**
  Large, sensitive horn
- **Ubiquitous radio signal**
  From every direction
- **Low frequency (microwave)**
  Low temperature (3K)
- **Echo of big bang**
  Evidence of expansion

BB model goes mainstream



Penzias and Wilson



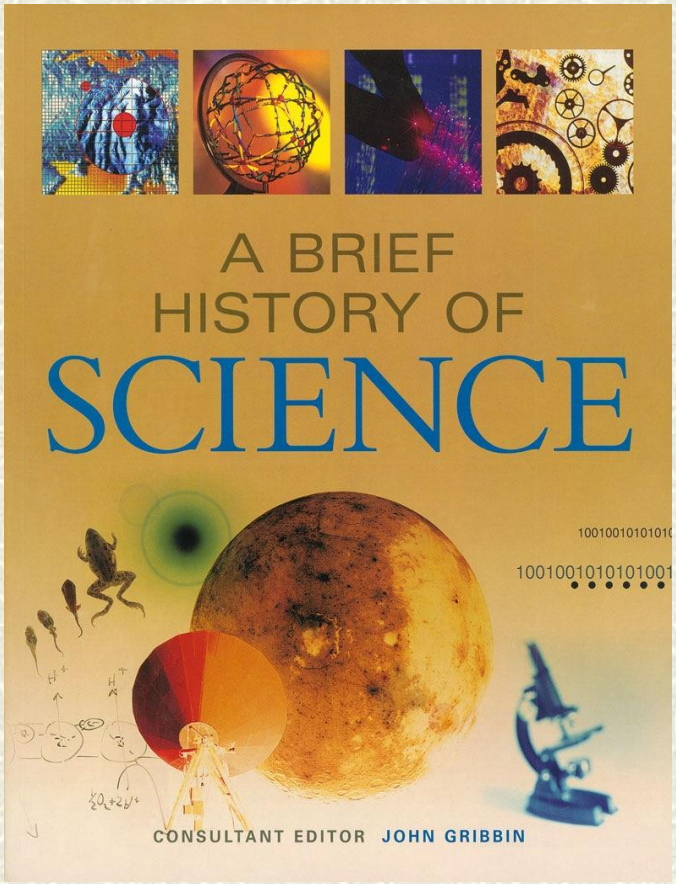
Why is Einstein's steady-state model interesting?

- **Unsuccessful theories important**
  Understanding the development of successful theories
  'Whig' histories avoided

- **A puzzle explained**
  Steady-state solutions not considered before 1948?
  Obvious possibility

- **Insight into Einstein's cosmology**
  Discards model rather than add new term to GFE
  Occam's razor approach

- **Some aspects of model still relevant**
  Dark energy, inflation



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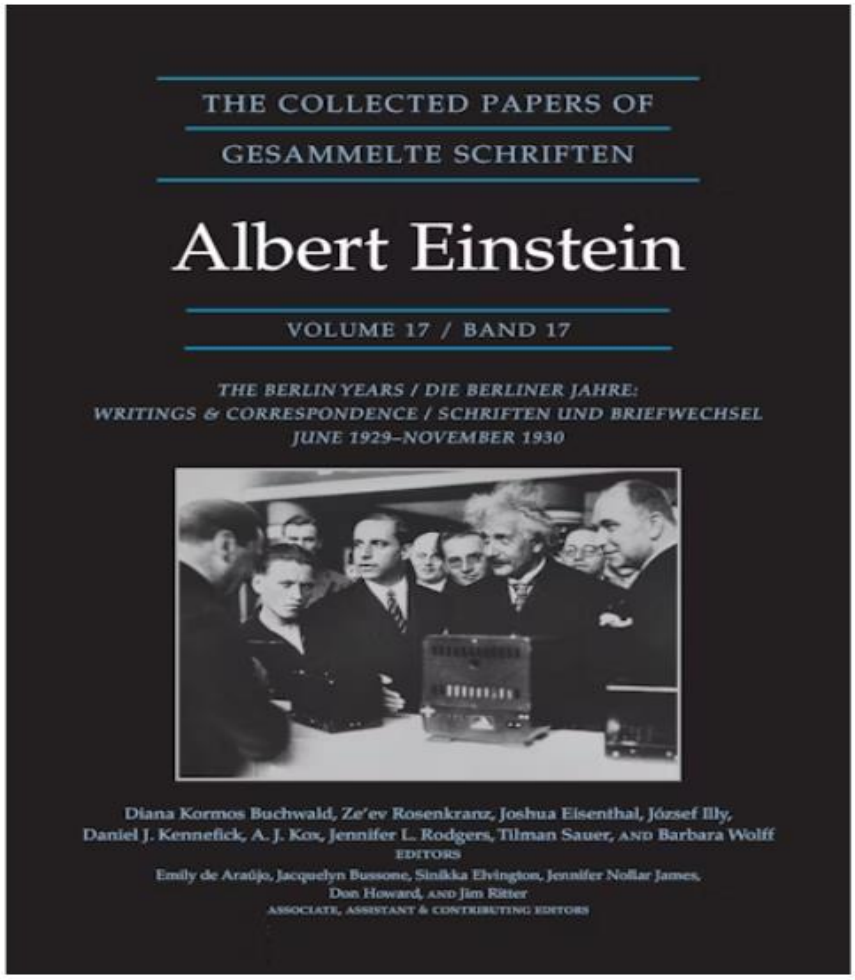

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Einstein's lost theory uncovered

Physicist explored the idea of a steady-state Universe in 1931.

Davide Castelvecchi

24 February 2014

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Einstein's Lost Theory Uncovered

The famous physicist explored the idea of a steady-state universe in 1931

nature

Feb 25, 2014 | By Davide Castelvecchi and Nature magazine

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New Discovery Reveals Einstein Tried To Devise A Steady State Model Of The Universe

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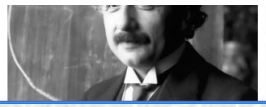

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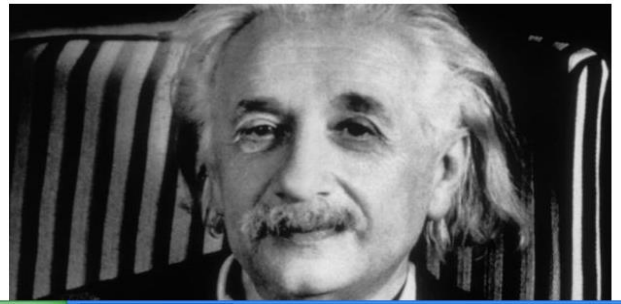
WIT researchers discover 'lost' Einstein model of universe

Scientists uncovered misfiled papers while searching Jerusalem university's online archive



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Einstein's steady-state theory: an abandoned model of the cosmos

Cormac O'Raifeartaigh, Brendan McCann, Werner Nahm, Simon Mitton

(Submitted on 1 Feb 2014 (v1), last revised 22 May 2014 (this version, v3))

We present a translation and analysis of an unpublished manuscript by Albert Einstein in which he attempted to construct a 'steady-state' model of the universe. The manuscript, which appears to have been written in early 1931, demonstrates that Einstein once explored a cosmic model in which the mean density of matter in an expanding universe is maintained constant by the continuous formation of matter from empty space. This model is very different to previously known Einsteinian models of the cosmos (both static and dynamic) but anticipates the later steady-state cosmology of Hoyle, Bondi and Gold in some ways. We find that Einstein's steady-state model contains a fundamental flaw and suggest that it was abandoned for this reason. We also suggest that he declined to explore a more sophisticated version because he found such theories rather contrived. The manuscript is of historical interest because it reveals that Einstein debated between steady-state and evolving models of the cosmos decades before a similar debate took place in the cosmological community.

Comments: 22 pages, 2 figures. Includes first English translation of unpublished Einstein manuscript. Accepted for publication in Eur.Phys.J.(H)
Subjects: **History and Philosophy of Physics (physics.hist-ph)**
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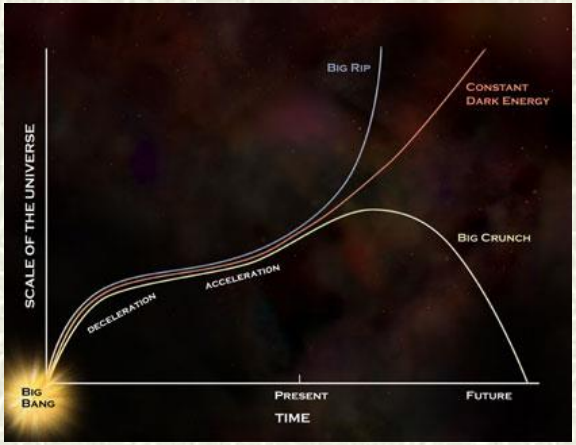
(or **arXiv:1402.0132v3 [physics.hist-ph]** for this version)

Einstein's steady-state model and cosmology today

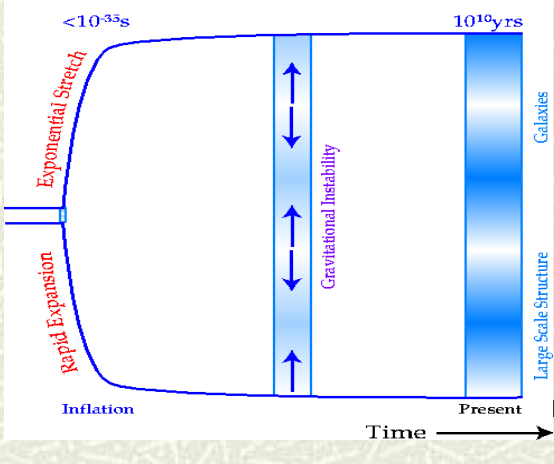


- **Dark energy (1998)**
  - *Accelerated expansion (observation)*
  - *Positive cosmological constant*

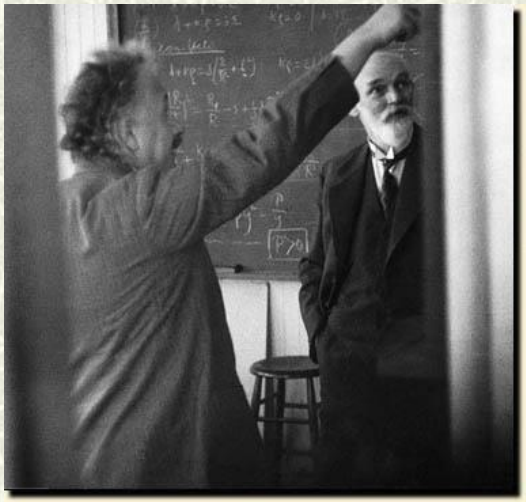
- **Einstein's dark energy**

"The conservation law is preserved in that, by setting the λ-term, space itself is not empty of energy; its validity is well known to be guaranteed by equations (1)."

- **Cosmic inflation**
  - *Inflationary models use de Sitter metric*
  - *Used in all steady-state models*
  - *Flat curvature, constant rate of matter creation*
  - *Different time-frame!*



Einstein-deSitter model (1932)



- **Remove curvature**

  Not known (Occam's razor)

- **Adopt Friedmann analysis**

  Time-varying universe with $\lambda = 0$, $k = 0$

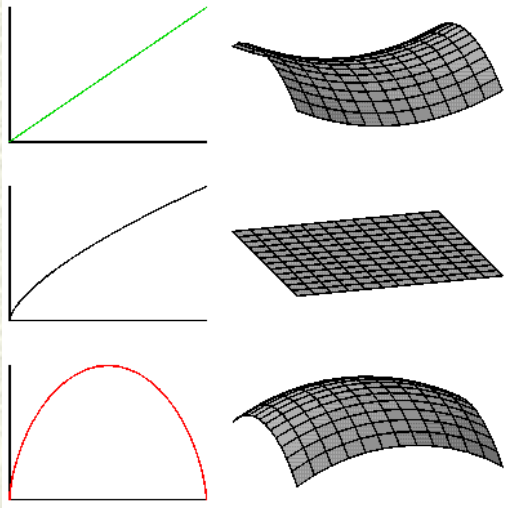
  Critical universe

- **Calculate critical density**

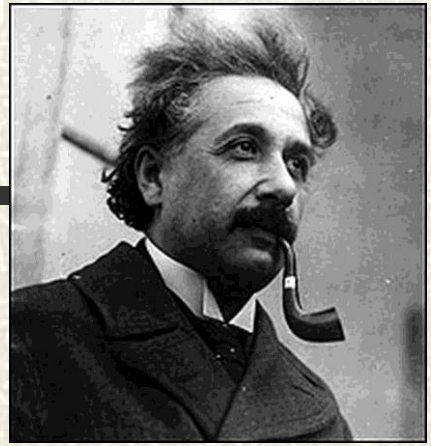
  10^{-28} g/cm^3 : agrees with astrophysics

- **<u>Well-known model</u>**

  Despite age problem



Einstein's 1931 model (F-E)



- **Numerical estimates of radius and density**

  Use Hubble parameter

  $P \sim 10^8$ light-years, $\rho \sim 10^{-26}$ g/cm^3

Oxford lecture (May 1931)

- **Calculations problematic**

  $H_0 \sim 500$ kms^{-1}Mpc^{-1} : $D^2 \sim 10^{-55}$ cm^{-2}

- **Age estimate problematic**

  Age from Friedman

- **<u>Not a periodic solution</u>**

  "Model fails at P = 0 "