

New perspectives on steady-state cosmology

From Einstein to Hoyle

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Einstein's steady-state model

✦ Unpublished AE manuscript

Written in early 1931

✦ Contains 'steady-state' model of the cosmos

Expanding universe of constant matter density

Continuous formation of matter from vacuum

Anticipates controversial theory (Hoyle)

✦ Inconsistent model

Fatal flaw

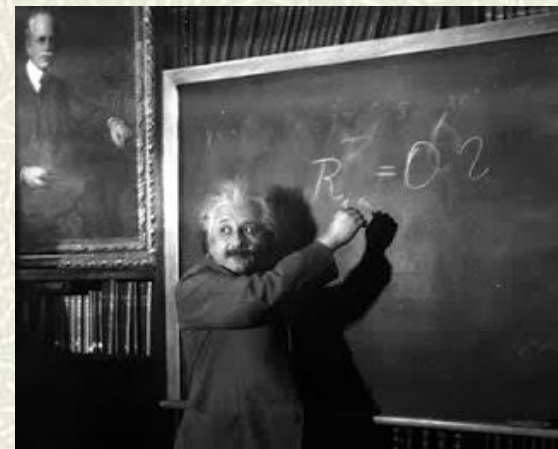
Abandoned, not amended

✦ Evolving models embraced

Friedman-Einstein, Einstein-de Sitter



Einstein in California (1931)



Hubble's law (1929)



✦ Spiral nebulae extra-galactic (1925)

100-inch reflector at Mt Wilson

Resolved Cepheid stars in several nebulae

Leavitt's period-luminosity relation

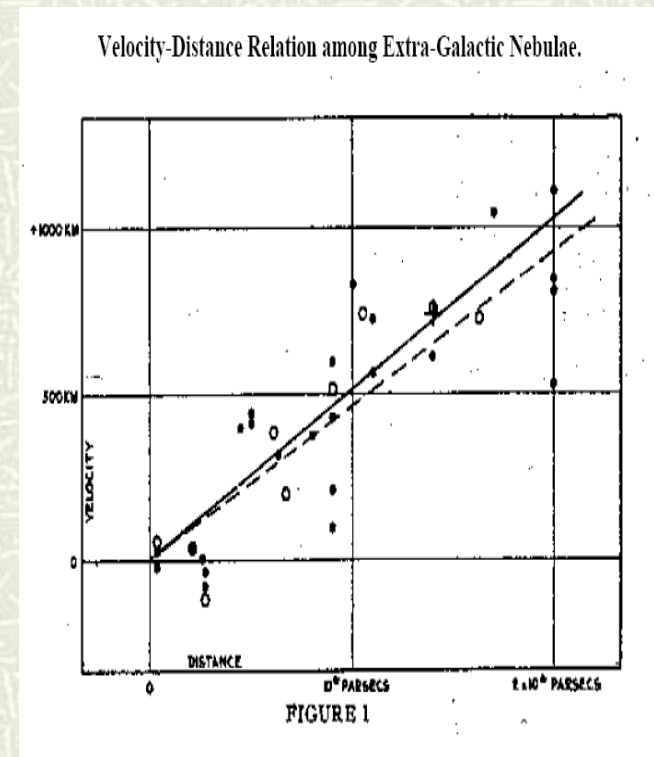
✦ A distance/redshift relation for the spirals?

Redshifts of the nebulae by VM Slipher (1915,1917)

✦ Approx linear relation (Hubble, 1929)

Some anomalies (Peacock)

Slipher not acknowledged



$$H = 585 \text{ kms}^{-1} \text{Mpc}^{-1}$$

A cosmic puzzle

What is causing recession of the galaxies ?

If redshifts are velocities

If effect is non-local

Newton's law of gravity

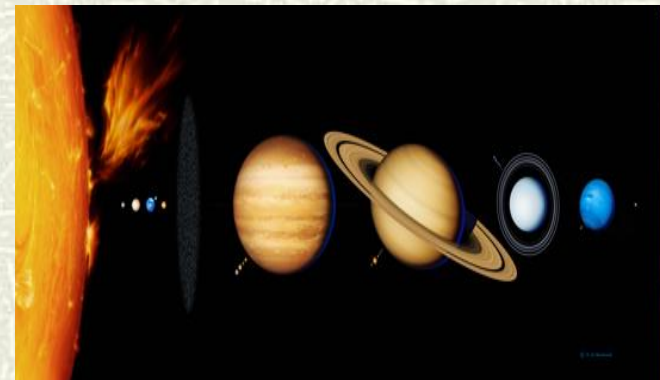
Gravity pulls in, not out

No other long range force for neutral matter

Space, time are fixed

Not affected by contents of universe

Eternal, infinite universe



General relativity (1915)

Space+ time = space-time

Space-time dynamic

Distorted by motion, mass

Gravity = curvature of space-time

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

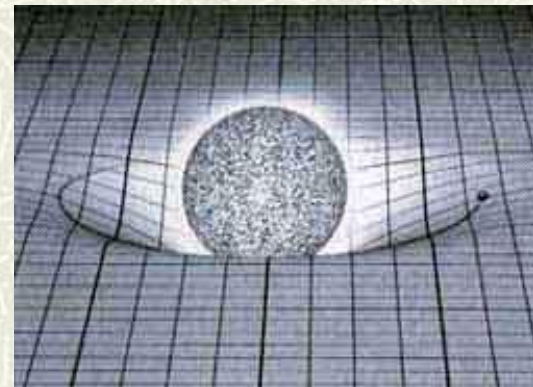
Empirical evidence

Perihelion of Mercury

Bending of starlight (Eddington, 1919)



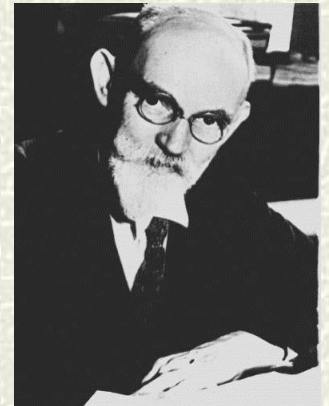
Albert Einstein



Einstein's universe (1917)

- ✦ **Apply general relativity to the cosmos**
- ✦ **Equations predict dynamic universe**
Expanding or contracting
- ✦ **No evidence for such a universe**
Unaware of Slipher redshifts
- ✦ **Add cosmic constant to give 'static' solution**

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



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)

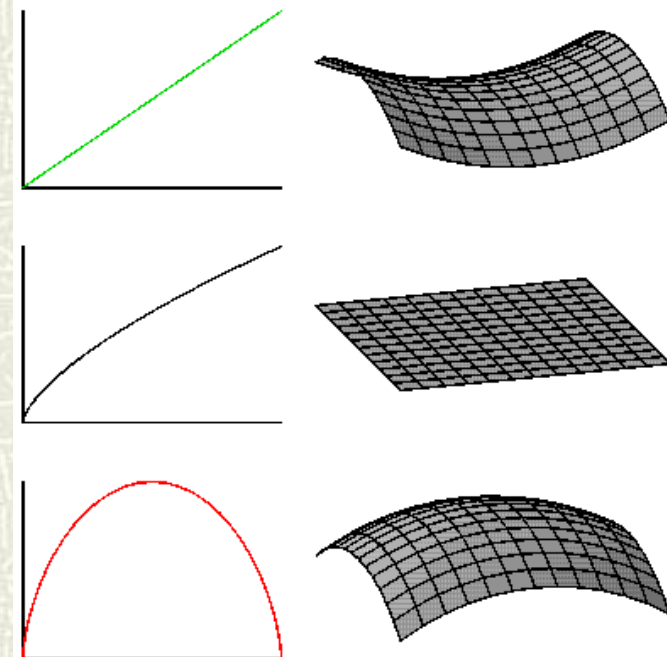
■ Evolving models (Zf. Ph.)

Matter density varies over time

■ Ignored by community

Disliked by Einstein

Correction and retraction



Lemaître's universe (1927)



Redshifts of galaxies = expansion of space?

Rate of expansion from mean distances and redshifts

$$H = 585 \text{ km/s/Mpc} \quad (1927)$$

Fr Georges Lemaître

No beginning: indefinite age

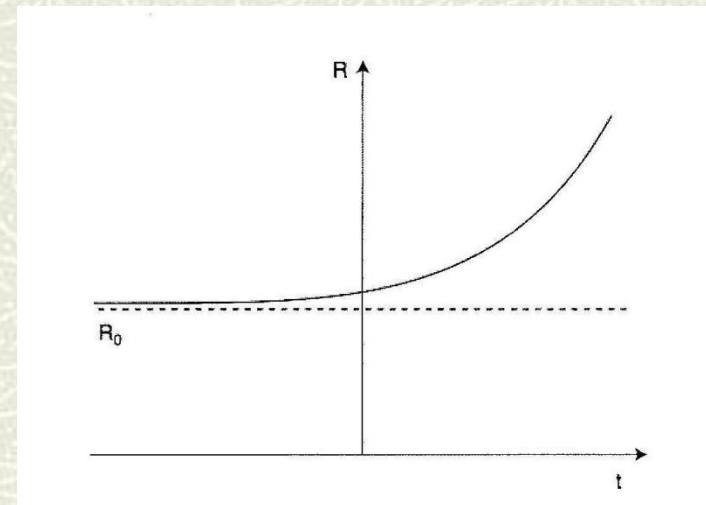
Starts from Einstein universe at $t = -\infty$

Not an empirical law

Rejected by Einstein

“Votre physique est abominable”

Ditto for Friedman models



An expanding universe? (1930-)

- **RAS meeting (1930)**

Eddington, de Sitter

If redshifts are velocities, and effect is non-local

- **Hubble's law = expansion of space?**

Static relativistic models don't fit data

Dynamic models required

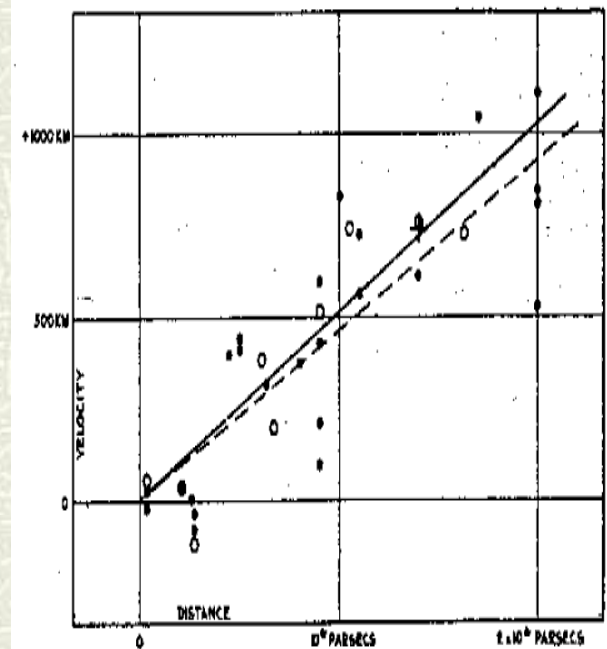
- **Friedman-Lemaître models**

Time-varying radius

Variable matter density

Evolving universe

Velocity-Distance Relation among Extra-Galactic Nebulae.



Cosmic expansion?

The expanding, evolving universe (1930 -)

- **Eddington (1930, 31)**

*On the instability of the Einstein universe
Expansion caused by condensation?*

- **de Sitter (1930, 31)**

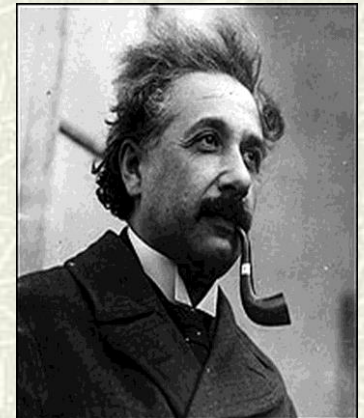
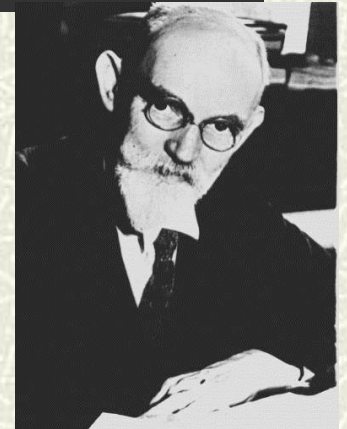
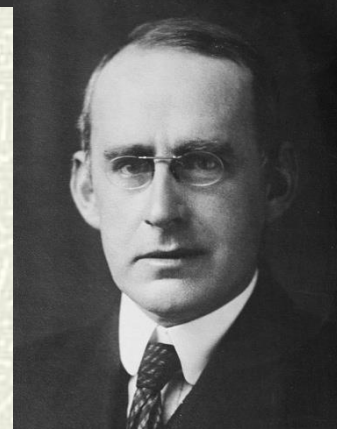
*Further remarks on the expanding universe
Expanding universes of every flavour*

- **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-de Sitter model $\lambda = 0, k = 0$*



If redshifts represent expansion...
Evolving models

New: Einstein's steady-state model (1931?)

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האוניברסיטה העברית בירושלים

Filed as draft of *F-E* model

Similar title, opening

Cites Hubble's law

Cites instability of static model

Cites evolving models

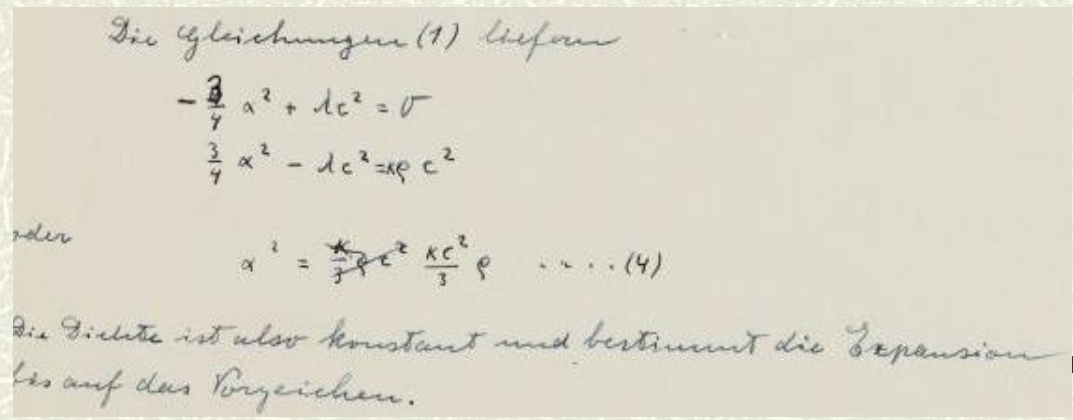
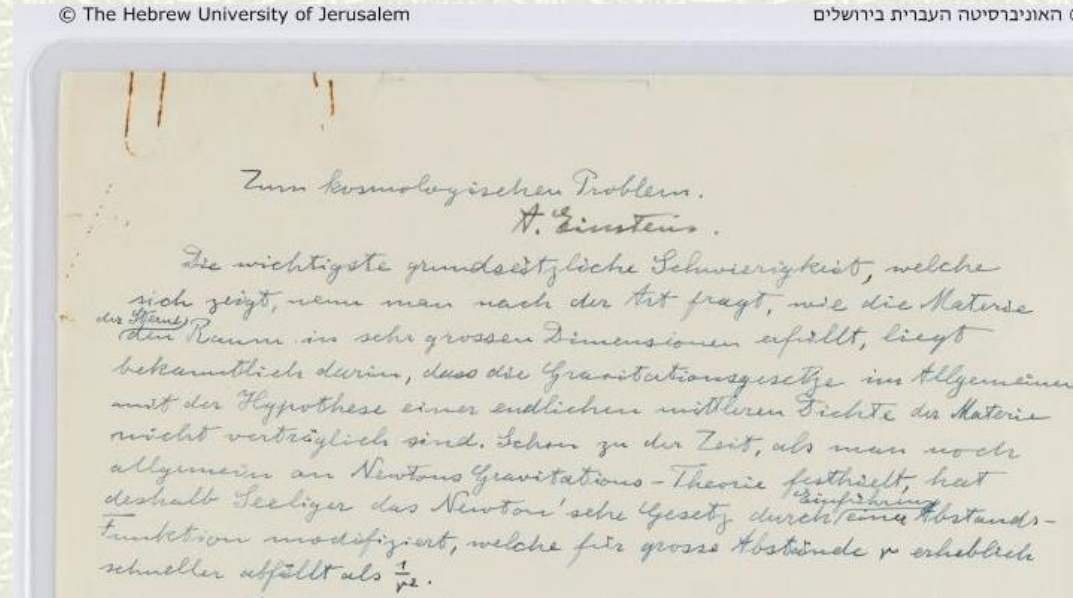
Discusses age problem

Proposes alternative solution

Expanding, unchanging cosmos?

Continuous creation of matter

Associates with λ - energy of space



Einstein's steady-state model: key quotes

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).”

An abandoned model

■ A fatal flaw

De Sitter metric

Matter creation associated with λ

■ Null result masked by error

Derivation incorrect

■ Einstein's crossroads

Identified problem on revision

Declined to amend GFE

■ Evolving models?

Less contrived and set $\lambda = 0$

Im Nachfolgenden will ich auf eine Lösung der Gleichung
(1) aufmerktsam machen, welche Hubble's Thatsachen gerecht
wird, und in welcher die Dichte zeitlich konstant ist. Diese
Lösung ist zwar in dem allgemeinen Schema Tolman's enthalten,
scheint aber bisher nicht in Betracht gezogen worden zu sein.
1. Ich setze an

$$ds^2 = -e^{\alpha t} (dx_1^2 + dx_2^2 + dx_3^2) + c^2 dt^2 \quad \dots (2)$$

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

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

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

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

Improved version (1962)

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



Hoyle and Narlikar (1962)

Evolving vs steady-state universe

Radio-astronomy

Galaxy distributions at different epochs

Cambridge 3C Survey (Ryle)



Cosmic microwave background

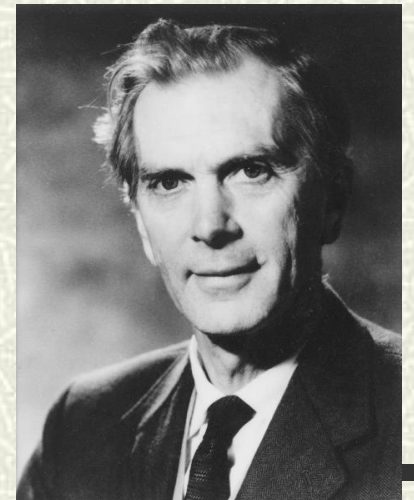
Low temperature, low frequency

Remnant of early universe

Optical astronomy

Amended timescale of expansion

(Baade, Sandage)



Significance of Einstein's steady-state model

✦ **Unsuccessful theories important**

Understanding the development of successful theories

✦ **New perspective on steady-state theory**

Logical possibility: not a crank theory

✦ **Insight into Einstein's philosophy**

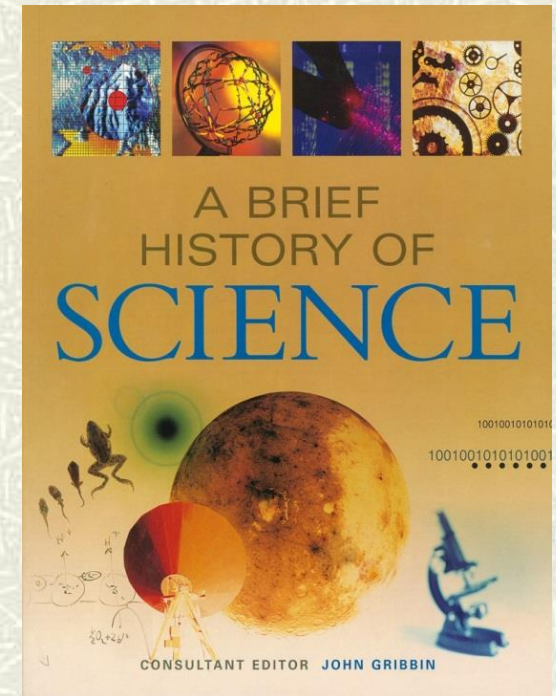
Discards model rather than add new term to GFE

Occam's razor approach

✦ **Insight into scientific progress**

Not Kuhnian paradigm shift

Slow dawning



Links with modern cosmology
Dark energy: creation energy and λ
Cosmic inflation: de Sitter metric

Einstein's lost theory uncovered

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

Daide Castelvechi

24 February 2014

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

2 comments, 2 called-out + Comment Now + Follow Comments

Almost 20 years before the late Fred Hoyle and his colleagues devised the [Steady State Theory](#), Albert Einstein toyed with a similar idea: that the universe was eternal, expanding outward with a consistent input of spontaneously generating matter.

An Irish physicist came across the paper last year and could hardly believe. According to this week's article in [Nature](#),

model of the universe very different to today's [Big Bang](#) Theory.

The manuscript, which hadn't been referred to by scientists for decades,



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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 Daide Castelvechi and Nature magazine

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



www.irishtimes.com/news/science/wit-researchers-discover-lost-einstein-model-of-universe-1.1713487

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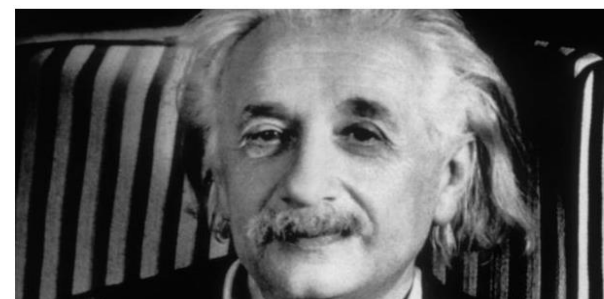
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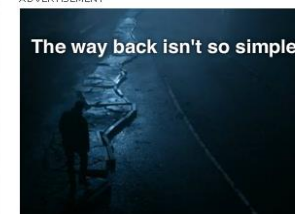
Scientists uncovered misfiled papers while searching Jerusalem university's online archive



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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!

