

# New perspectives on steady-state cosmology

*From Einstein to Hoyle*

Cormac O'Raiheartaigh (Waterford Inst of Technology)  
Simon Mitton (University of Cambridge)

# 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## # Unpublished AE manuscript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*

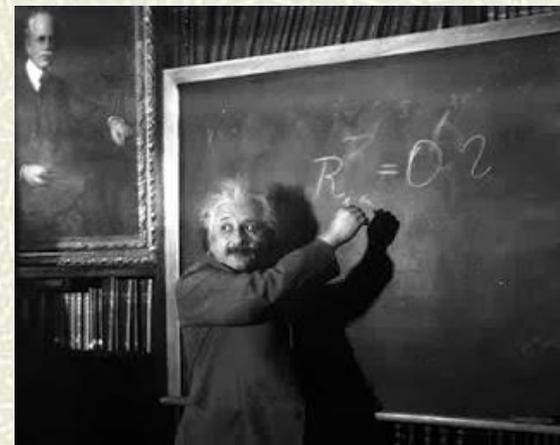
*Abandoned, not amended*

## # 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*

Velocity-Distance Relation among Extra-Galactic Nebulae.

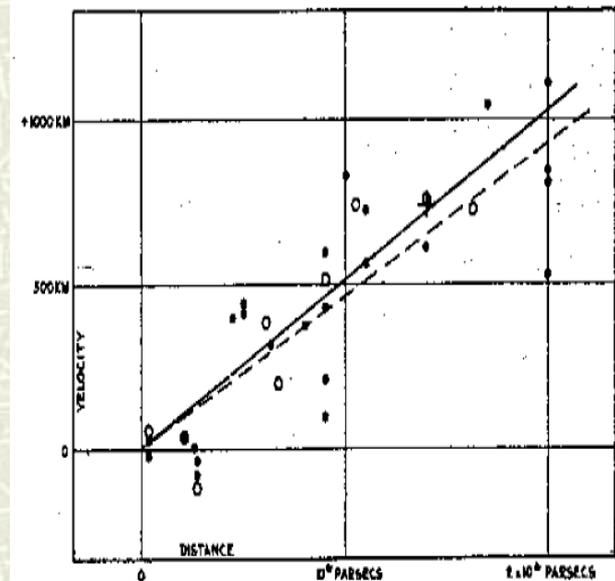


FIGURE 1

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

# A cosmic puzzle

## # What is causing recession of the galaxies ?

*If redshifts are velocities*

*If effect is non-local*

## # Newton's law of gravity

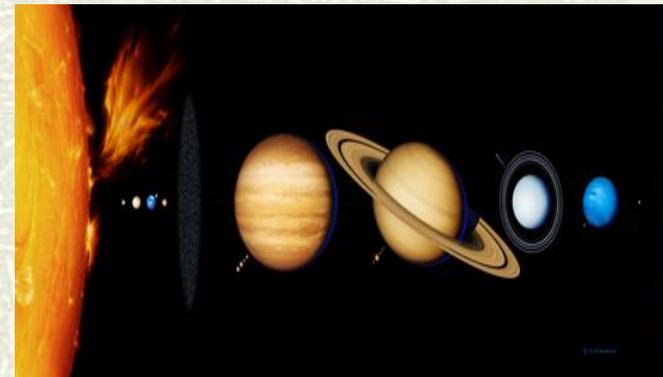
*Gravity pulls in, not out*

*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**

$$\mathbf{G}_{\mu\nu} = \frac{8\pi G}{c^4} \mathbf{T}_{\mu\nu}$$

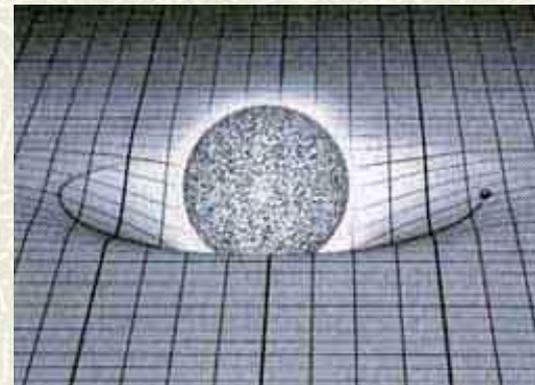
## # **Empirical evidence**

*Perihelion of Mercury*

*Bending of starlight (Eddington, 1919)*



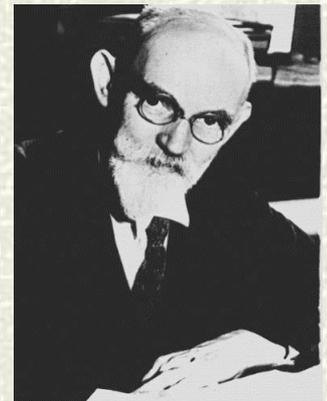
*Albert Einstein*



# 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)*

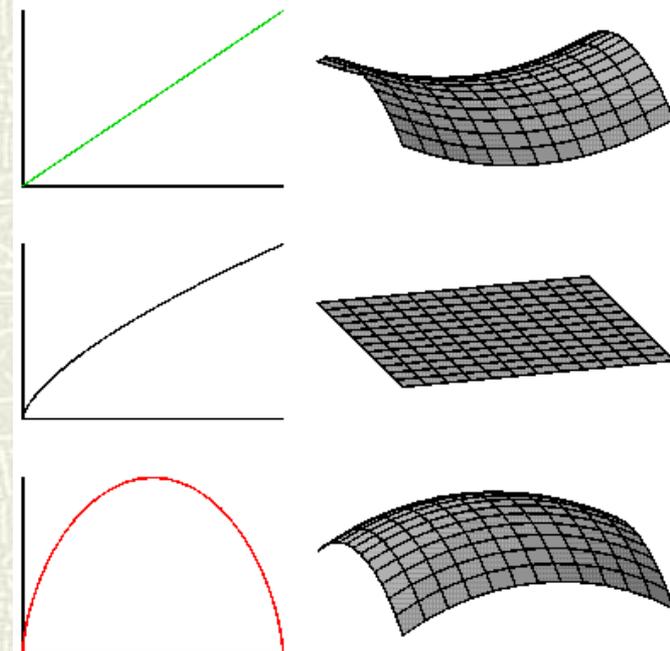
## ▣ Evolving models (Zf. Ph.)

*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

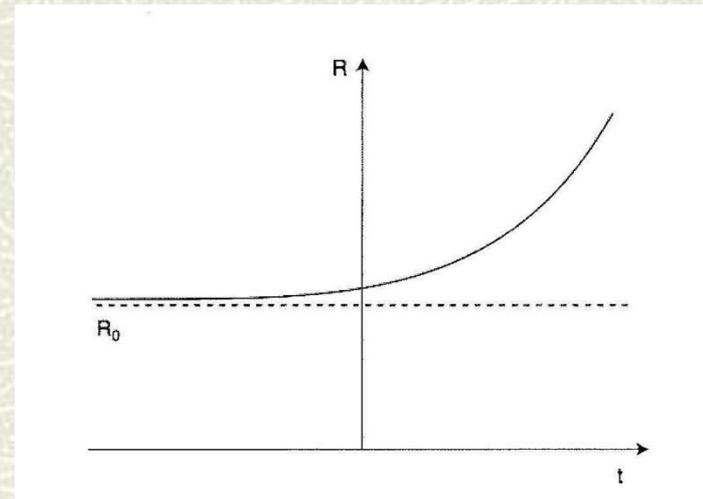
*Starts from Einstein universe at  $t = -\infty$*

*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*

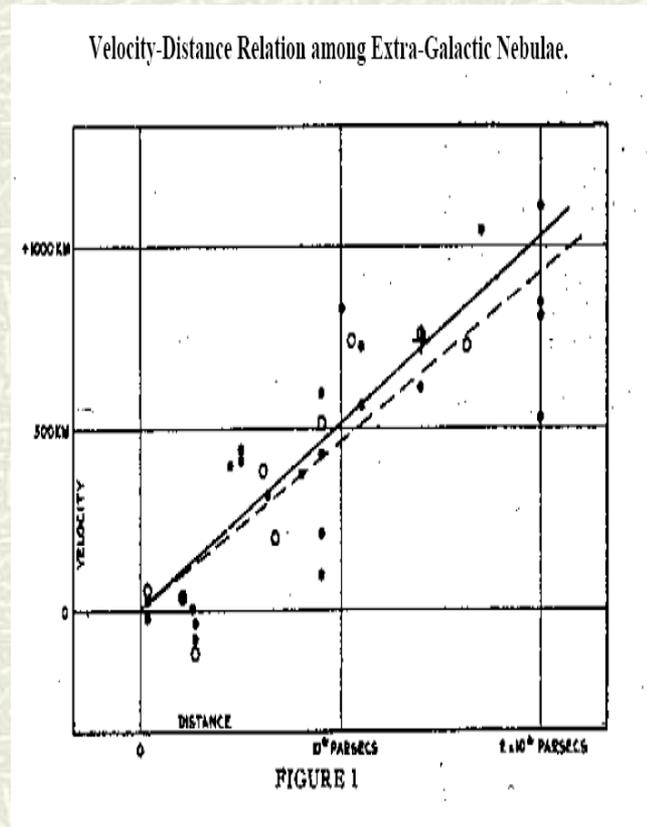
*Dynamic models required*

- **Friedman-Lemaître models**

*Time-varying radius*

*Variable matter density*

*Evolving universe*



*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)**

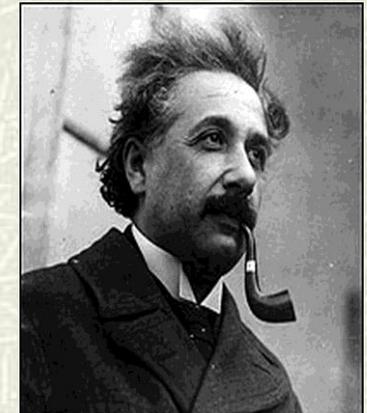
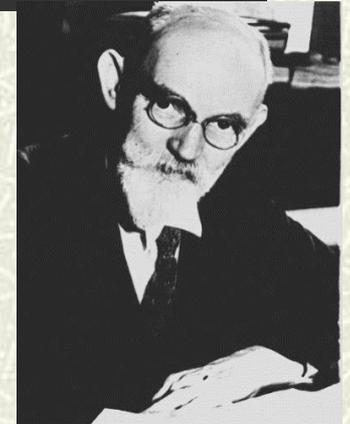
*Further remarks on the expanding universe  
Expanding universes of every flavour*

- **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?)

© The Hebrew University of Jerusalem

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**

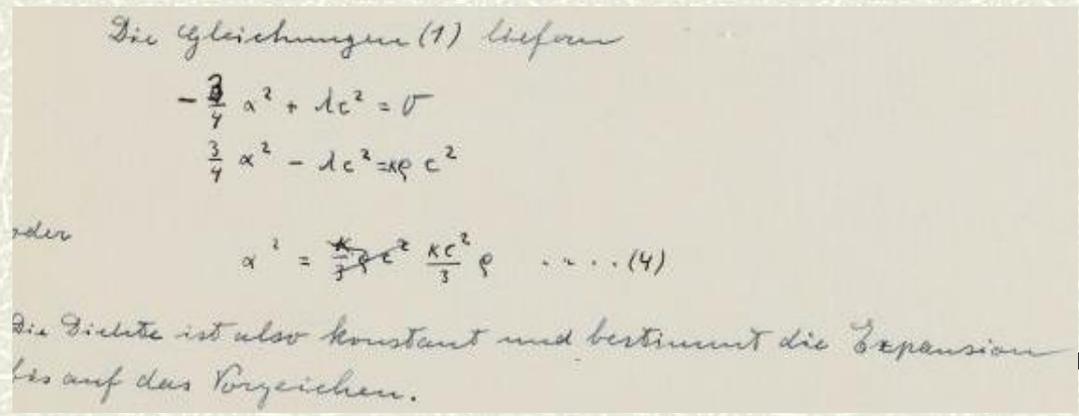
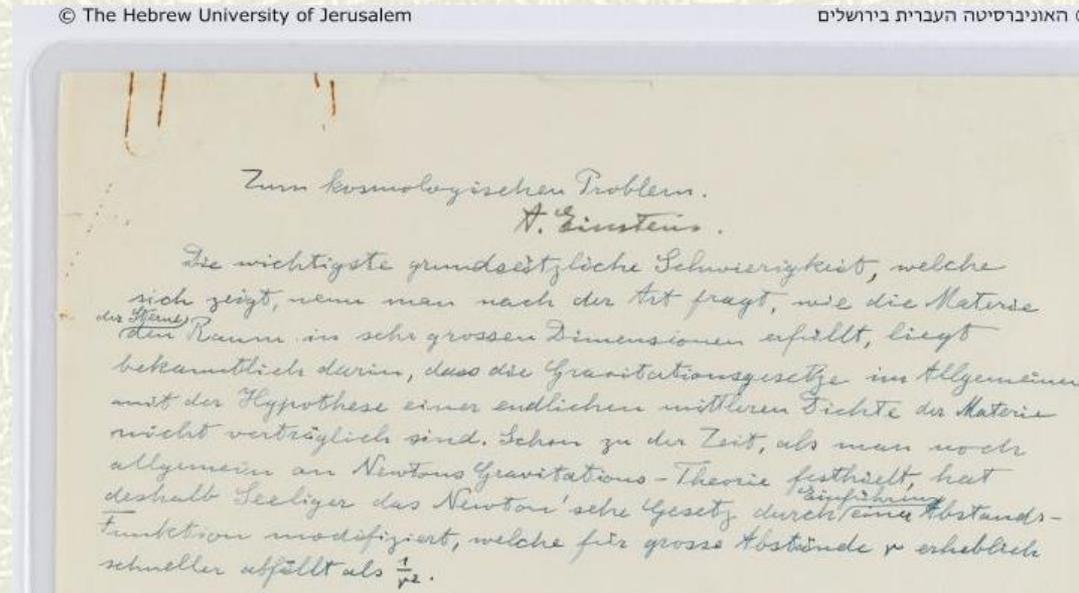
*Discusses age problem*

## # **Proposes alternative solution**

*Expanding, unchanging cosmos?*

*Continuous creation of matter*

*Associates with  $\lambda$  - 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  $\lambda$ -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  $\lambda$*

## # 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

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

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

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

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 $\lambda$ 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)

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

# Evolving vs steady-state universe

## # Radio-astronomy

*Galaxy distributions at different epochs*

*Cambridge 3C Survey (Ryle)*



## # Cosmic microwave background

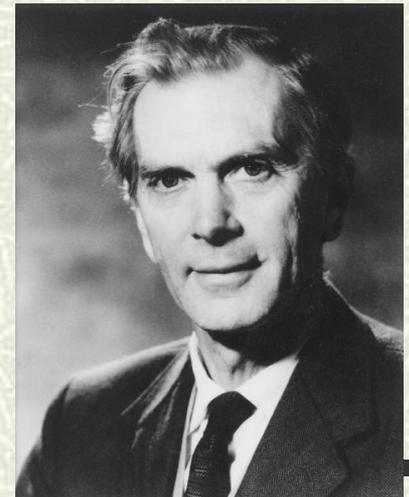
*Low temperature, low frequency*

*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

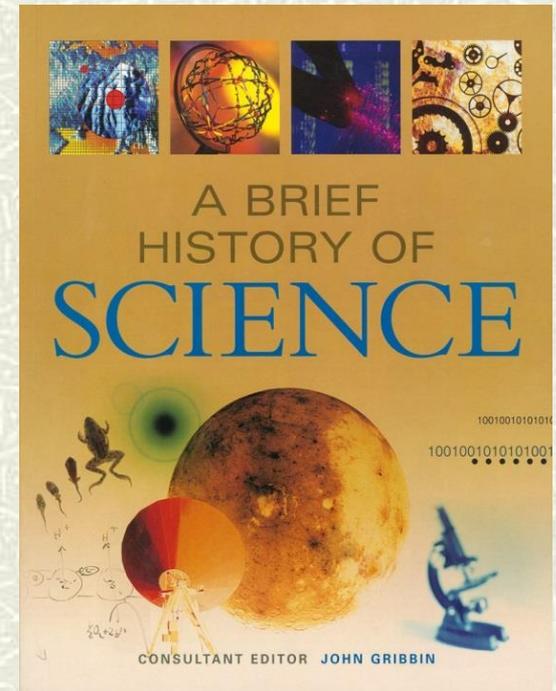
*Discards model rather than add new term to GFE*

*Occam's razor approach*

## # Insight into scientific progress

*Not Kuhnian paradigm shift*

*Slow dawning*



*Links with modern cosmology*  
*Dark energy: creation energy and  $\lambda$*   
*Cosmic inflation: de Sitter metric*

NATURE | NEWS   

**Einstein's lost theory uncovered**

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

**Daive Castelvechi**

24 February 2014

Physics » Nature   Email  Print

**Einstein's Lost Theory Uncovered**

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

**nature**

Feb 25, 2014 | By Davide Castelvechi 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**

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,



 The straight talking savings bank

 Like You like this.

News / Science

**WIT researchers discover 'lost' Einstein model of universe**

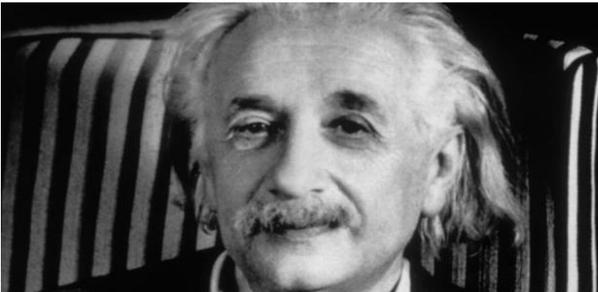
Scientists uncovered misfiled papers while searching Jerusalem university's online archive

**Latest Ireland »**

- 12:26 Quinn confirms Flannery approached hm with Rehab concerns
- 09:07 Man in his twenties stabbed in north Dublin
- 09:05 Family hope public appeal will help daughter beat cancer
- 08:42 Gardaí investigate death of woman in Dublin
- 08:25 Flannery faces call from all parties to attend PAC

ADVERTISEMENT

**The way back isn't so simple**




# 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  $\lambda$ -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!*

