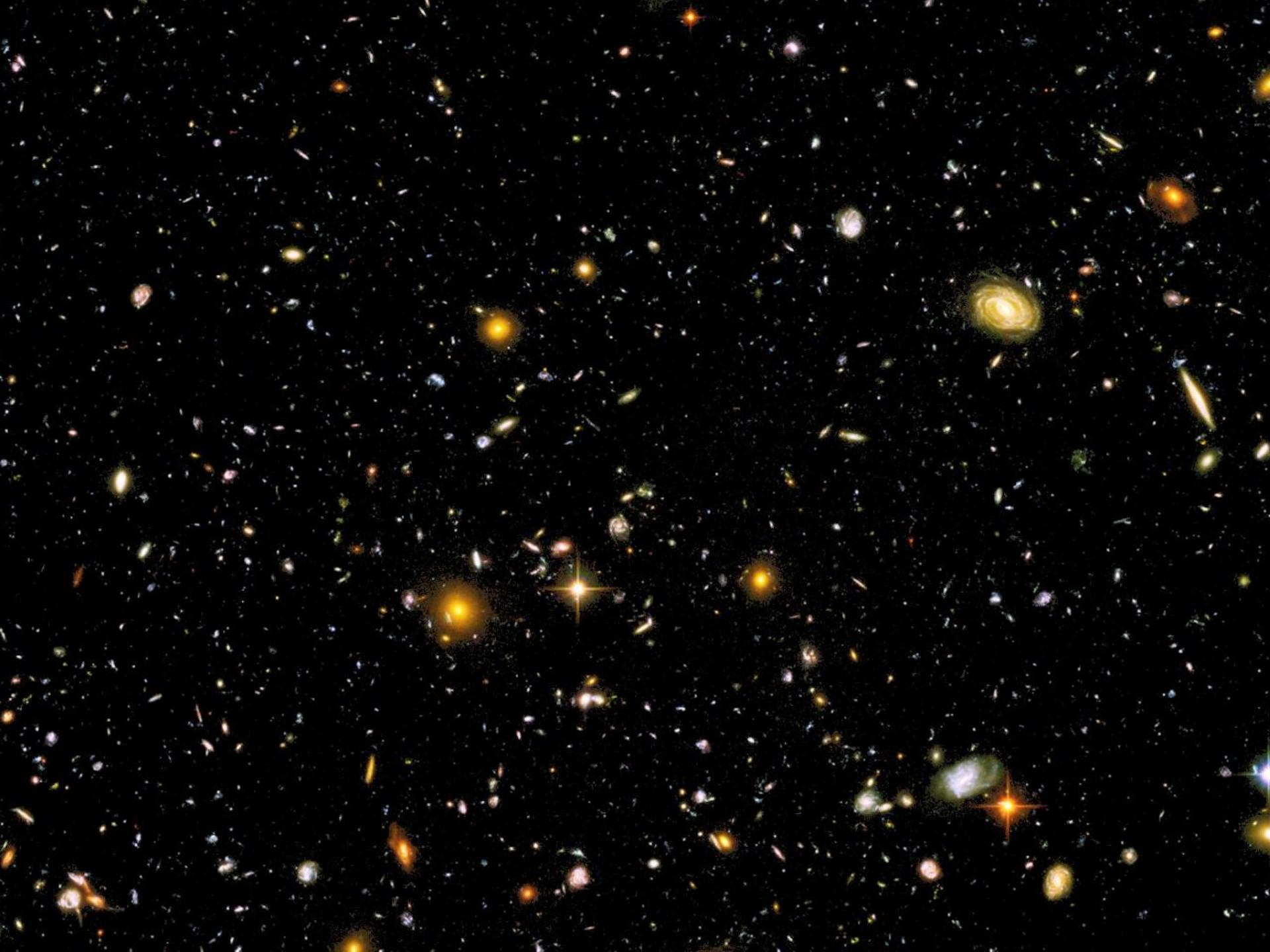
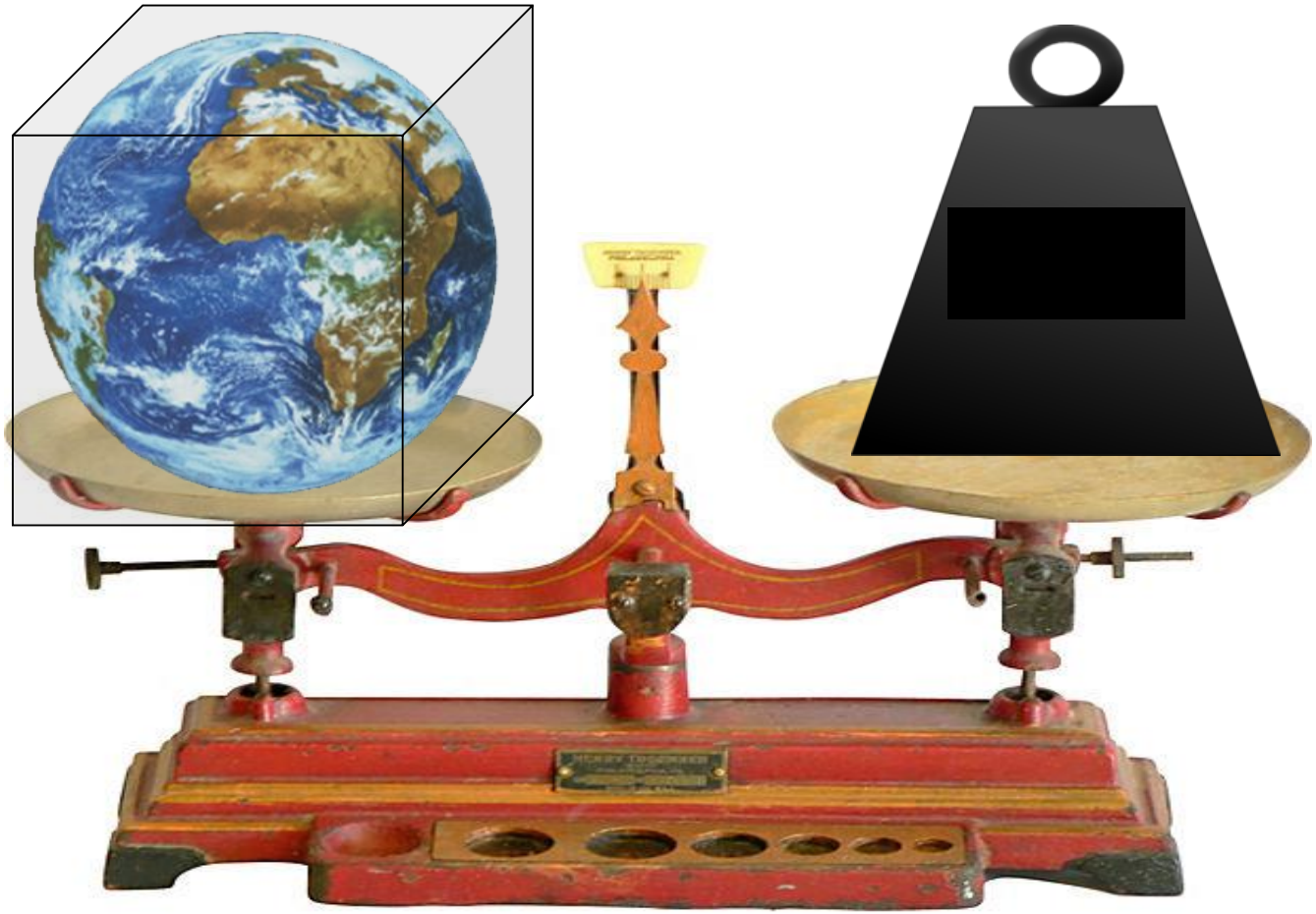
Introduction – The expanding Universe

Edvard Mörtsell

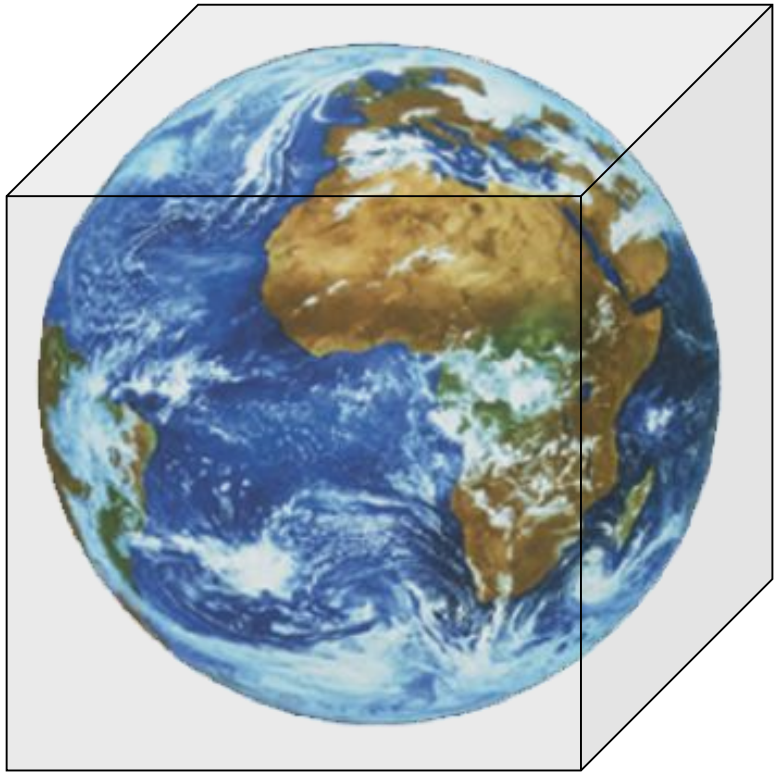
Cosmology and Astroparticle Physics FK7050

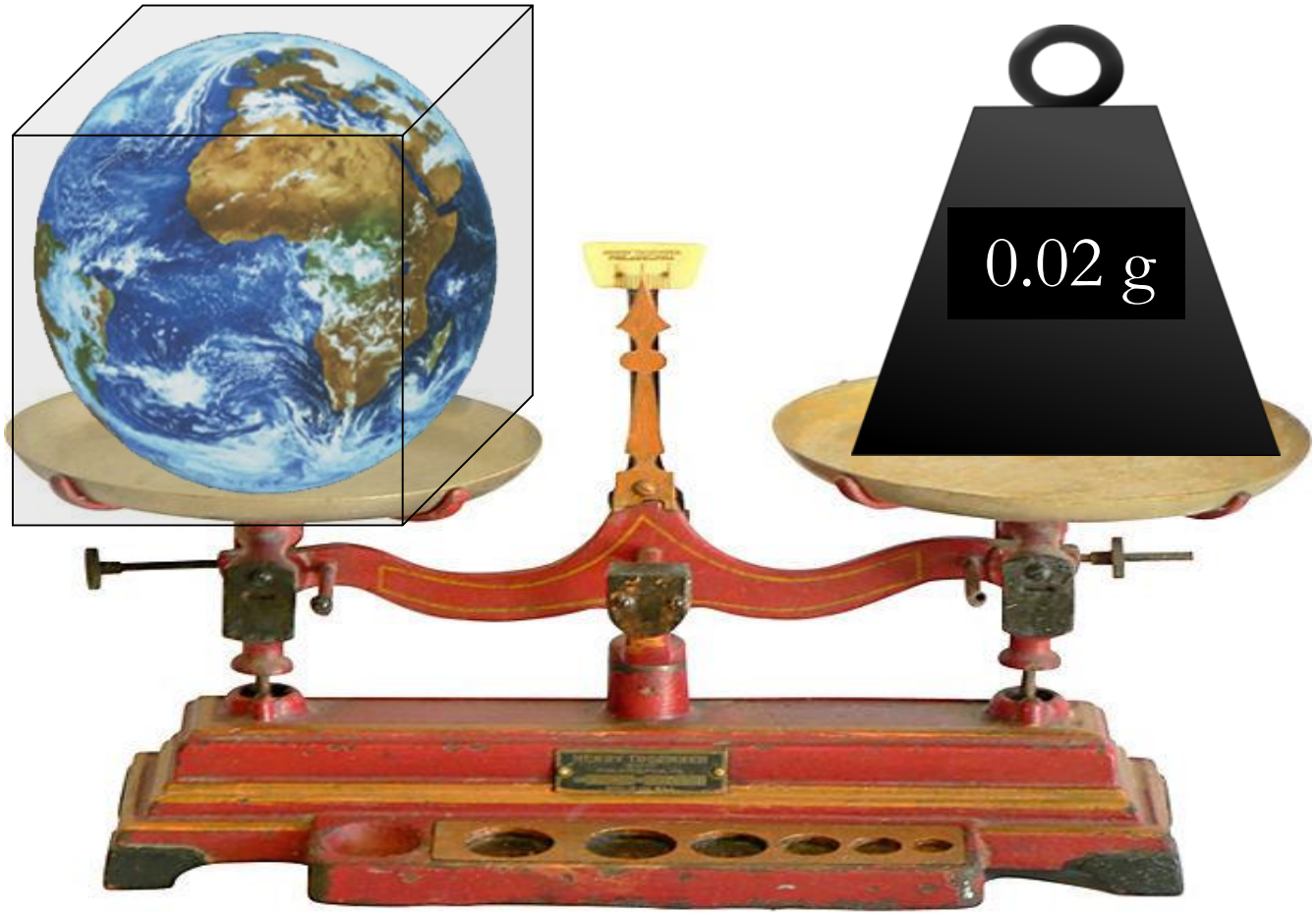




Assume a cube large enough to fit the Earth has the average density of the Universe. What is its mass?

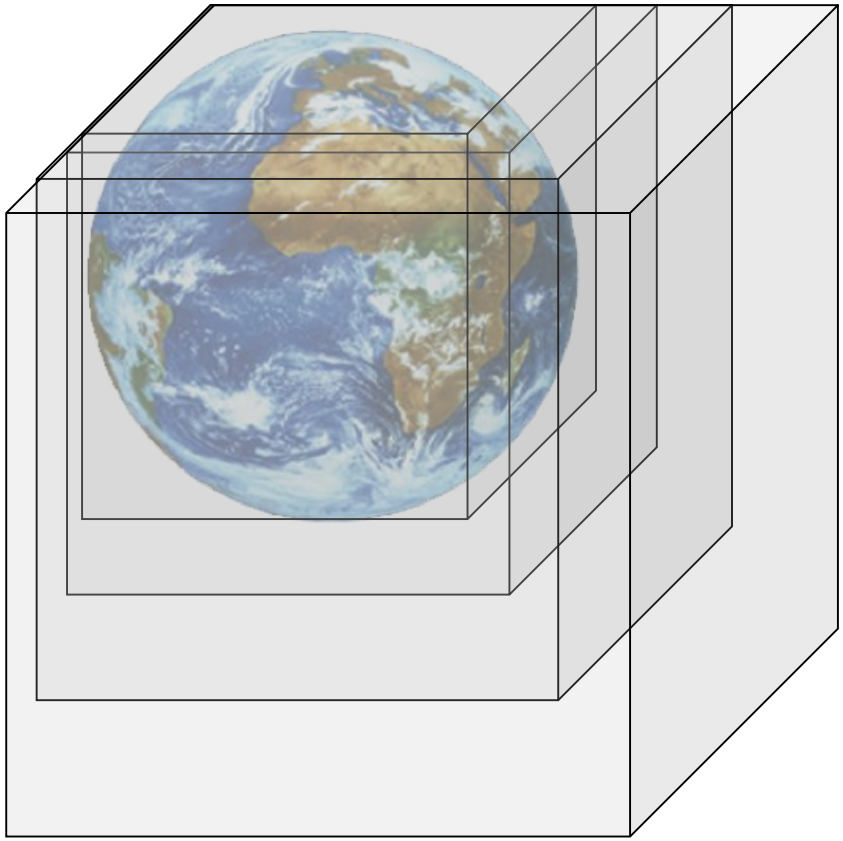
- ❑ 0.02 g
- ❑ 2 kg
- ❑ 200 000 kg




0.02 g

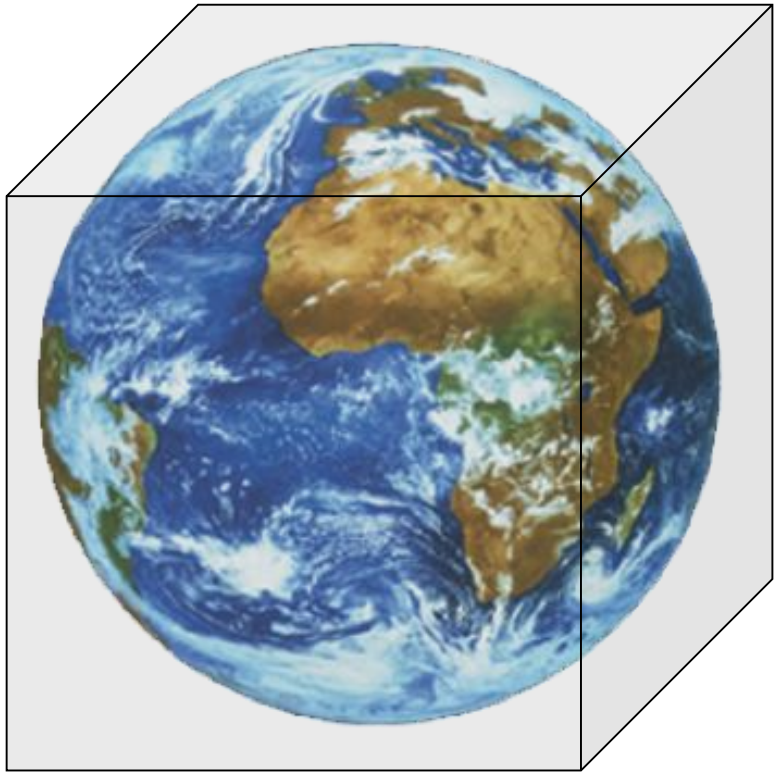
13 000 km

Year 2018



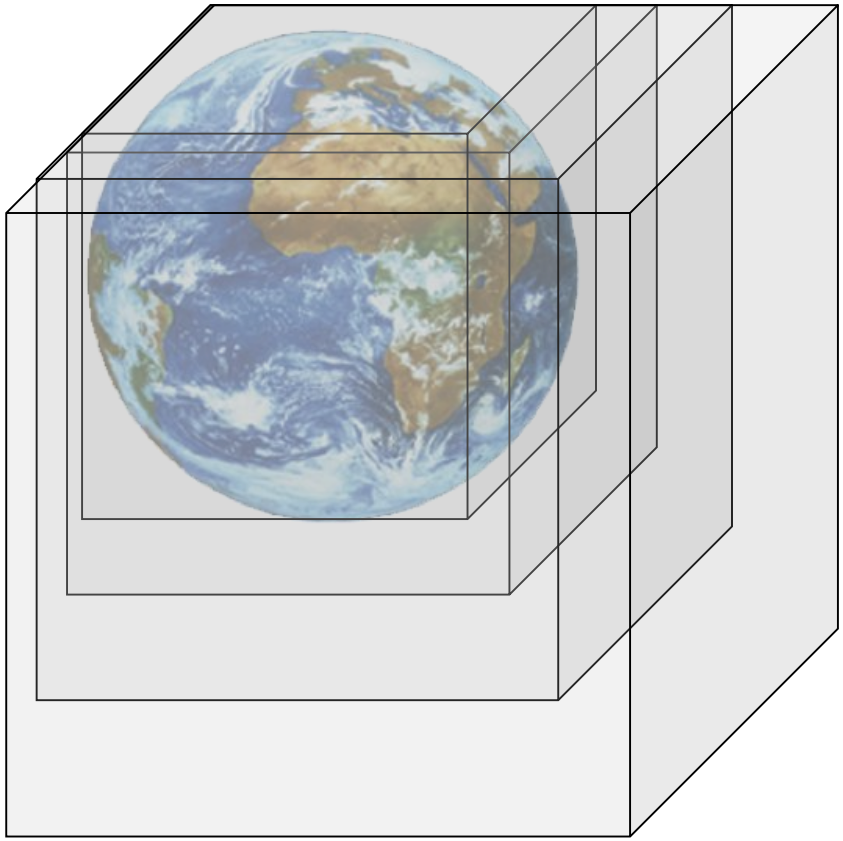
How much would the side of a cube in empty space large enough to fit the Earth grow in a year?

- ❑ 1 mm
- ❑ 10 m
- ❑ 100 km



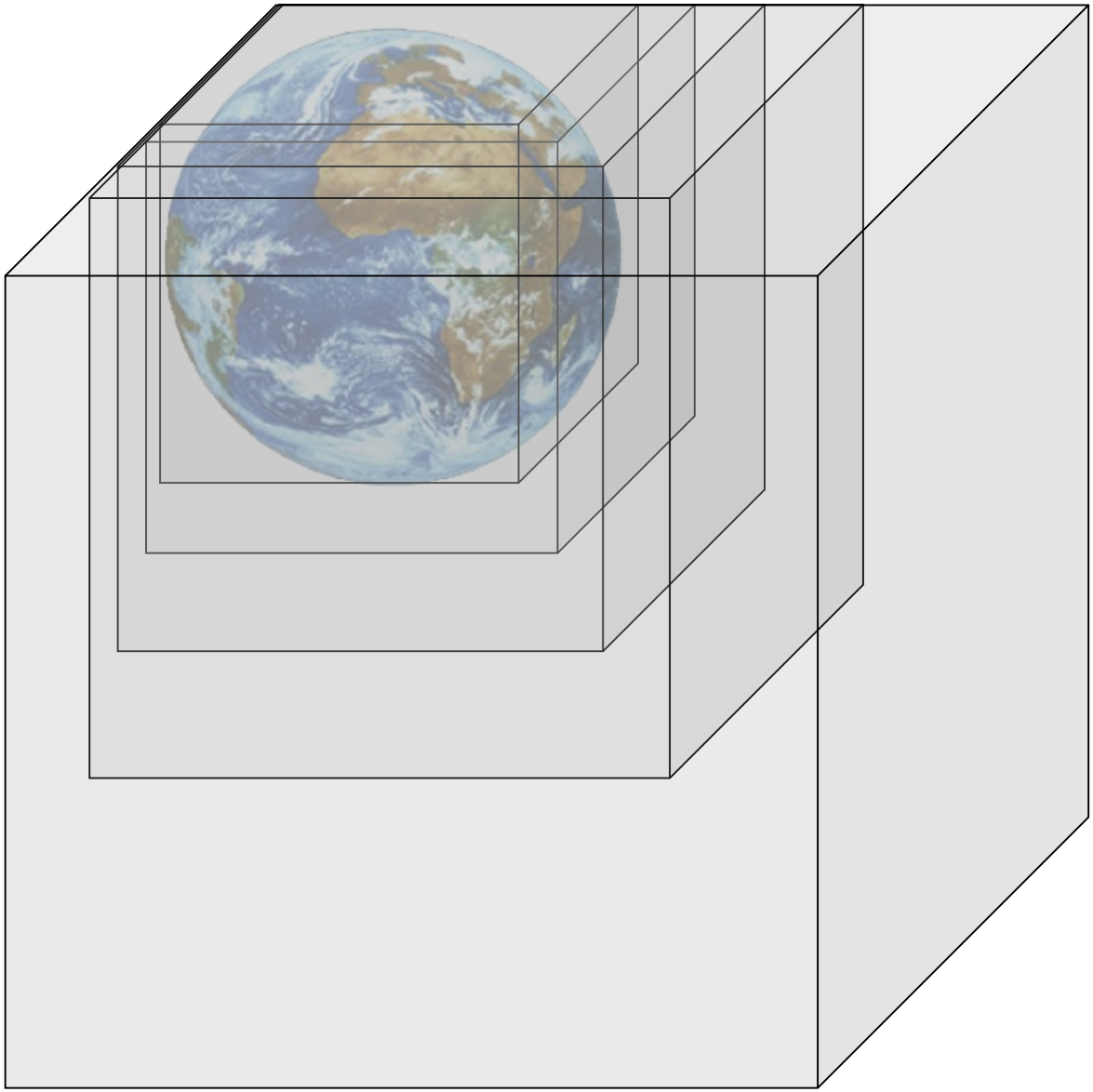
13 000 km + 1 mm

Year 2019



26 000 km

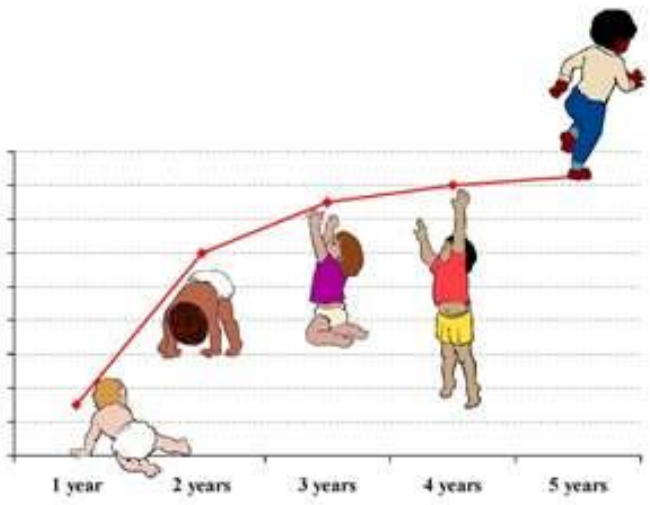
Year 14 000 002 018



Introduction – The accelerating Universe

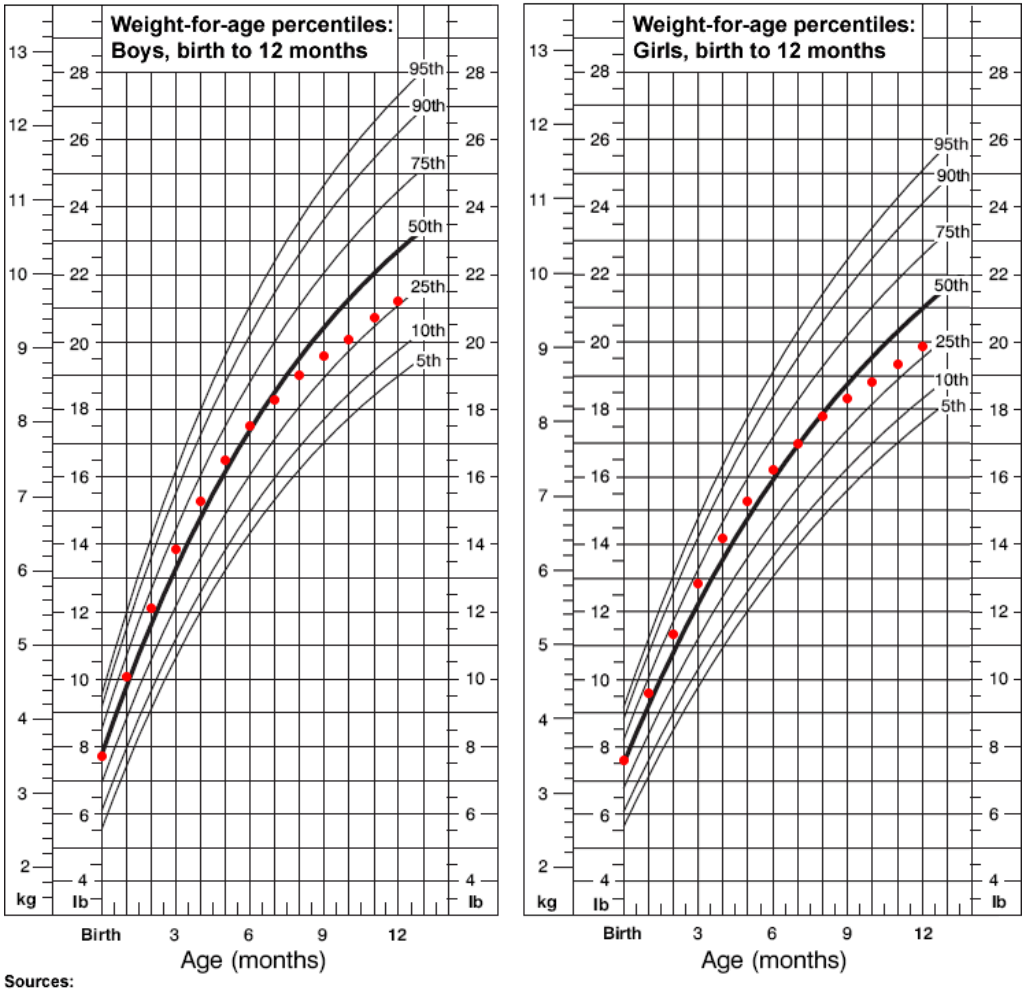
Edvard Mörtsell

Cosmology and Astroparticle Physics FK7050



Average Growth Patterns of Breastfed Infants

The red points plotted on the CDC Growth Charts represent the average weight-for-age for a small set of infant boys and girls who were breastfed for at least 12 months (see references).

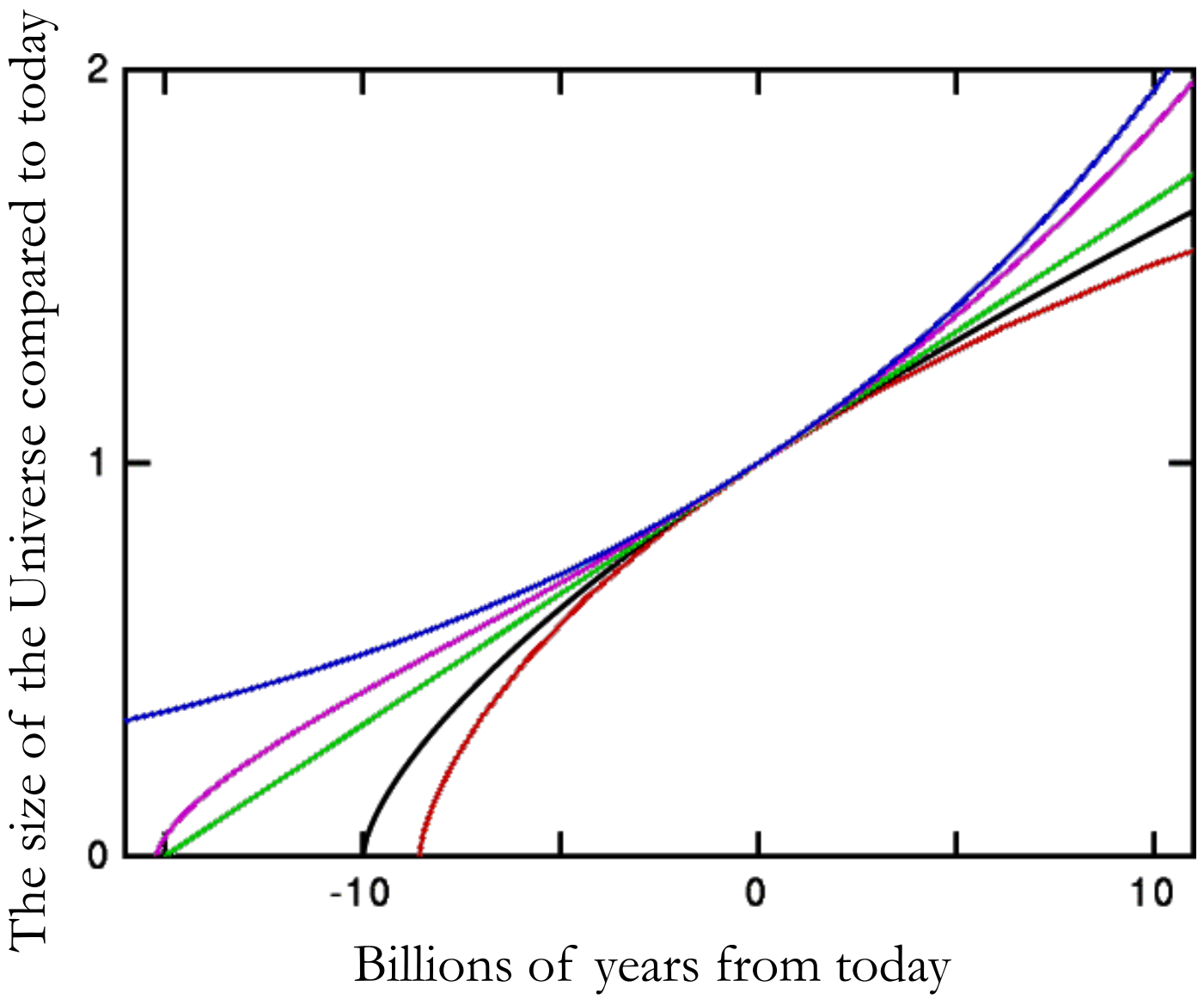


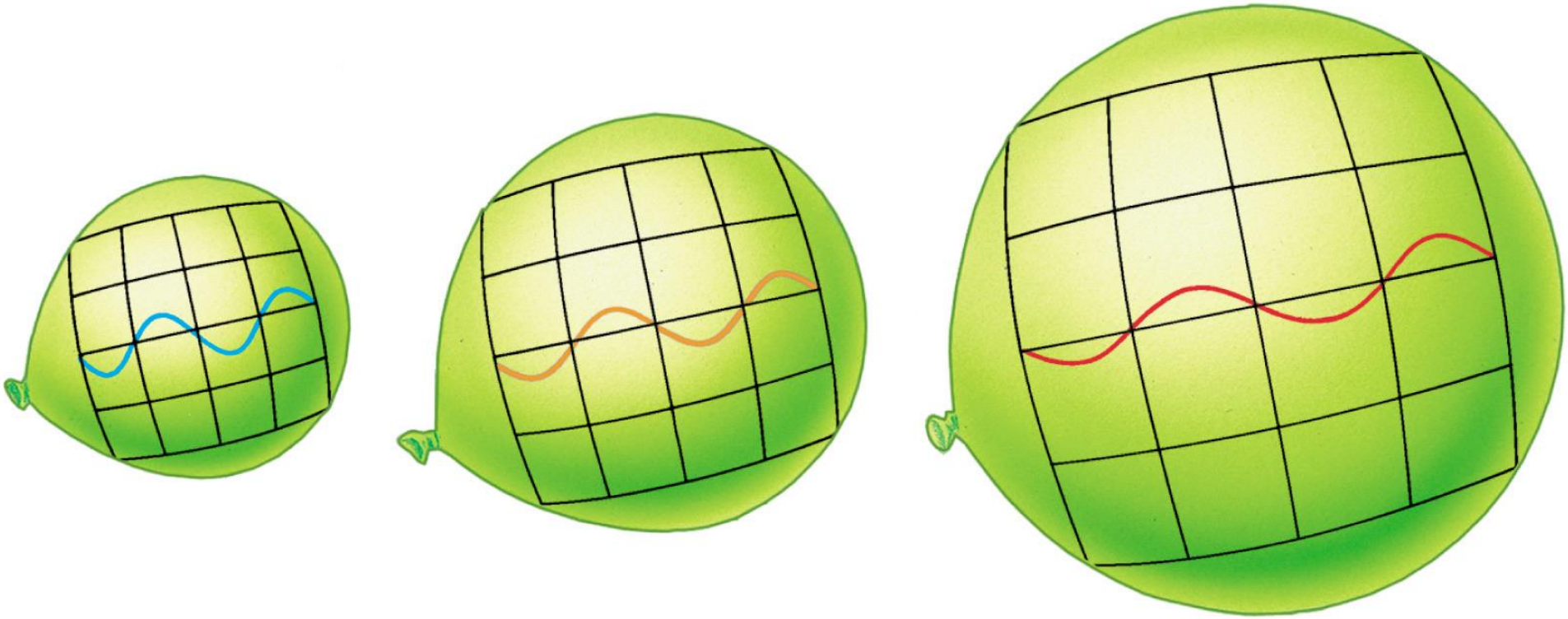
Sources:

- **Base chart** -- CDC Growth Charts: United States, Published May 30, 2000.

Graphic by kellymom.com, 2004

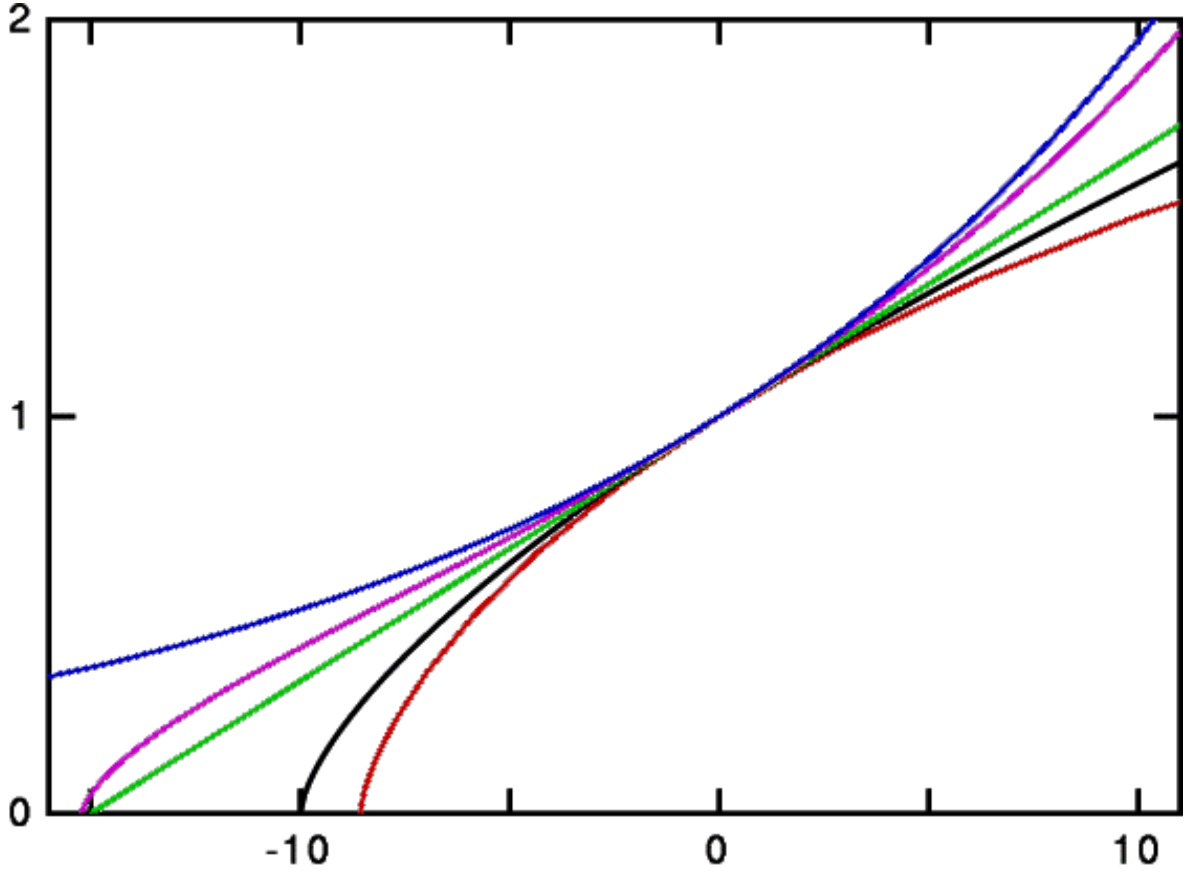
- **Breastfed baby data points** -- WHO Working Group on Infant Growth. An Evaluation of Infant Growth: a summary of analyses performed in preparation for the WHO Expert Committee on Physical Status: the use and interpretation of anthropometry. (WHO/NUT/94.8). Geneva: World Health Organization, 1994, p.21.

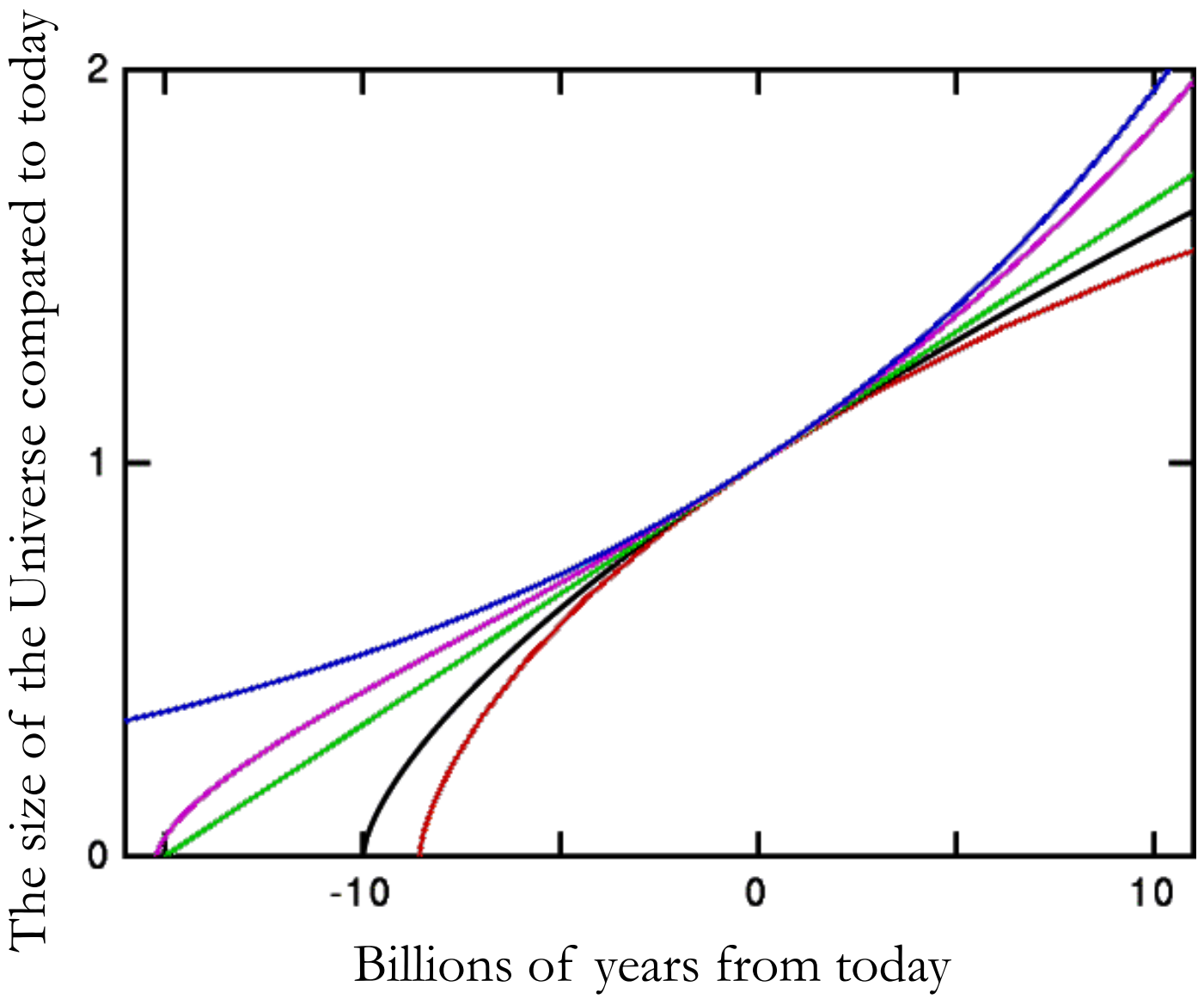

The size of the Universe compared to today
2
1
0
-10
0
10
Billions of years from today



What line describes best the growth curve of our Universe?

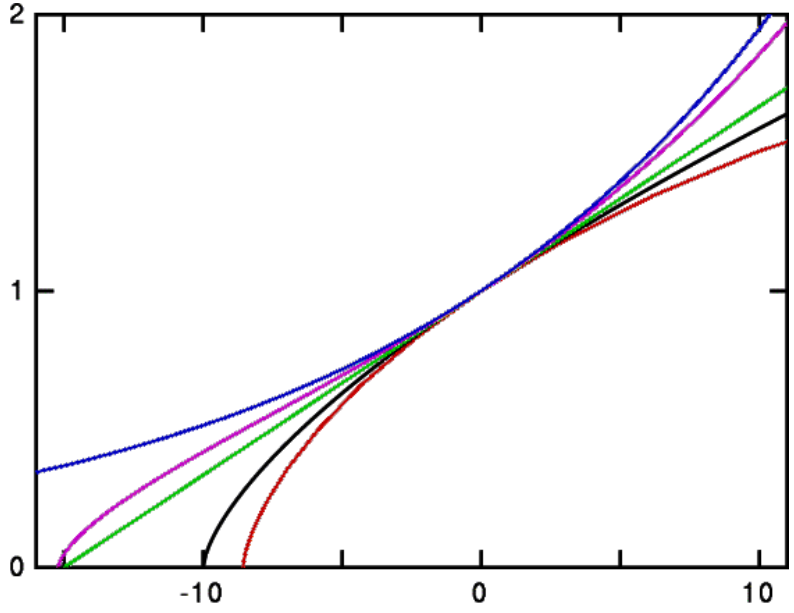
- ❑ Blue
- ❑ Purple
- ❑ Green
- ❑ Black
- ❑ Red

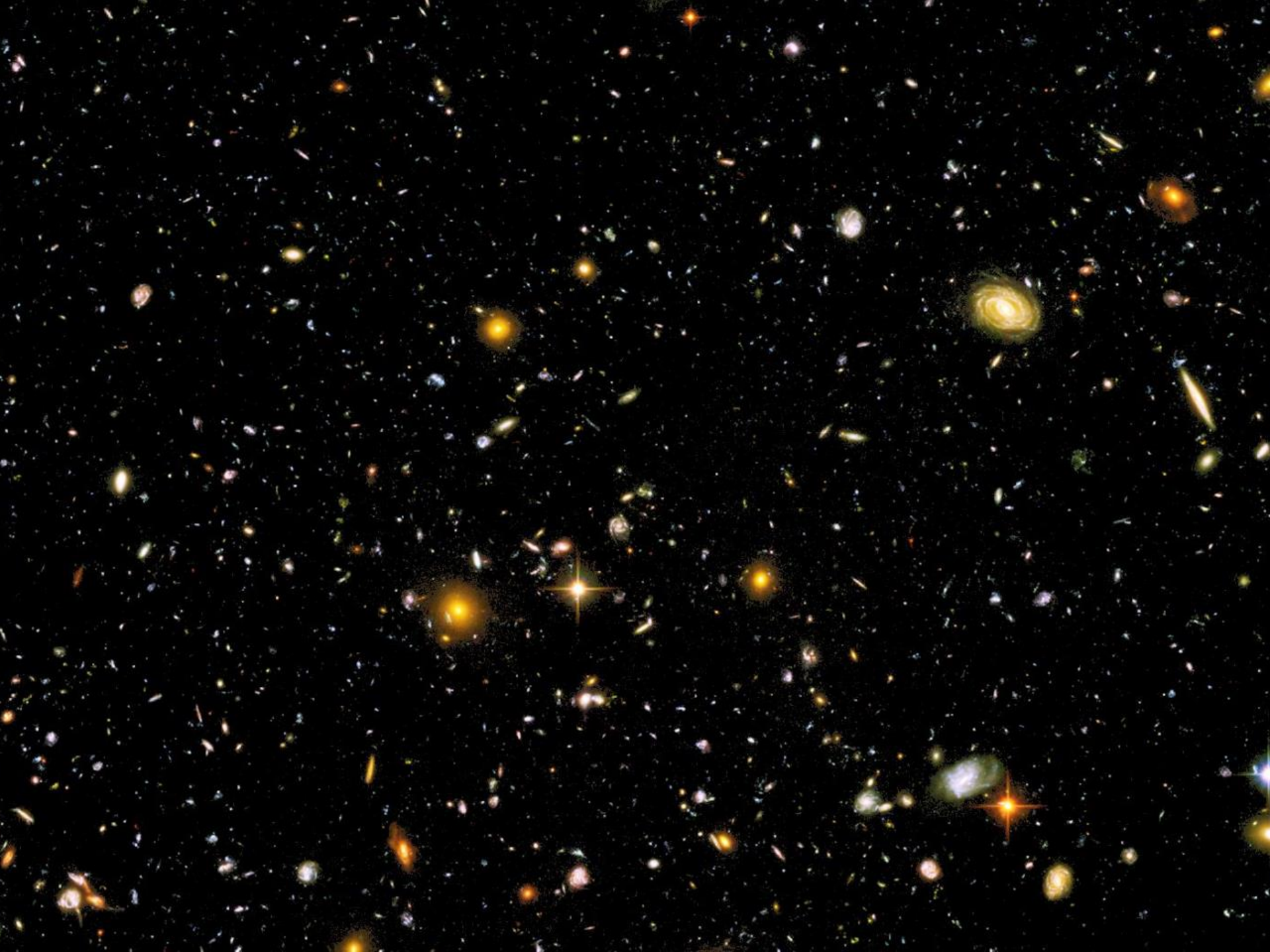



The size of the Universe compared to today
2
1
0
-10
0
10
Billions of years from today

What measured quantity does the common slope of the lines today correspond to?

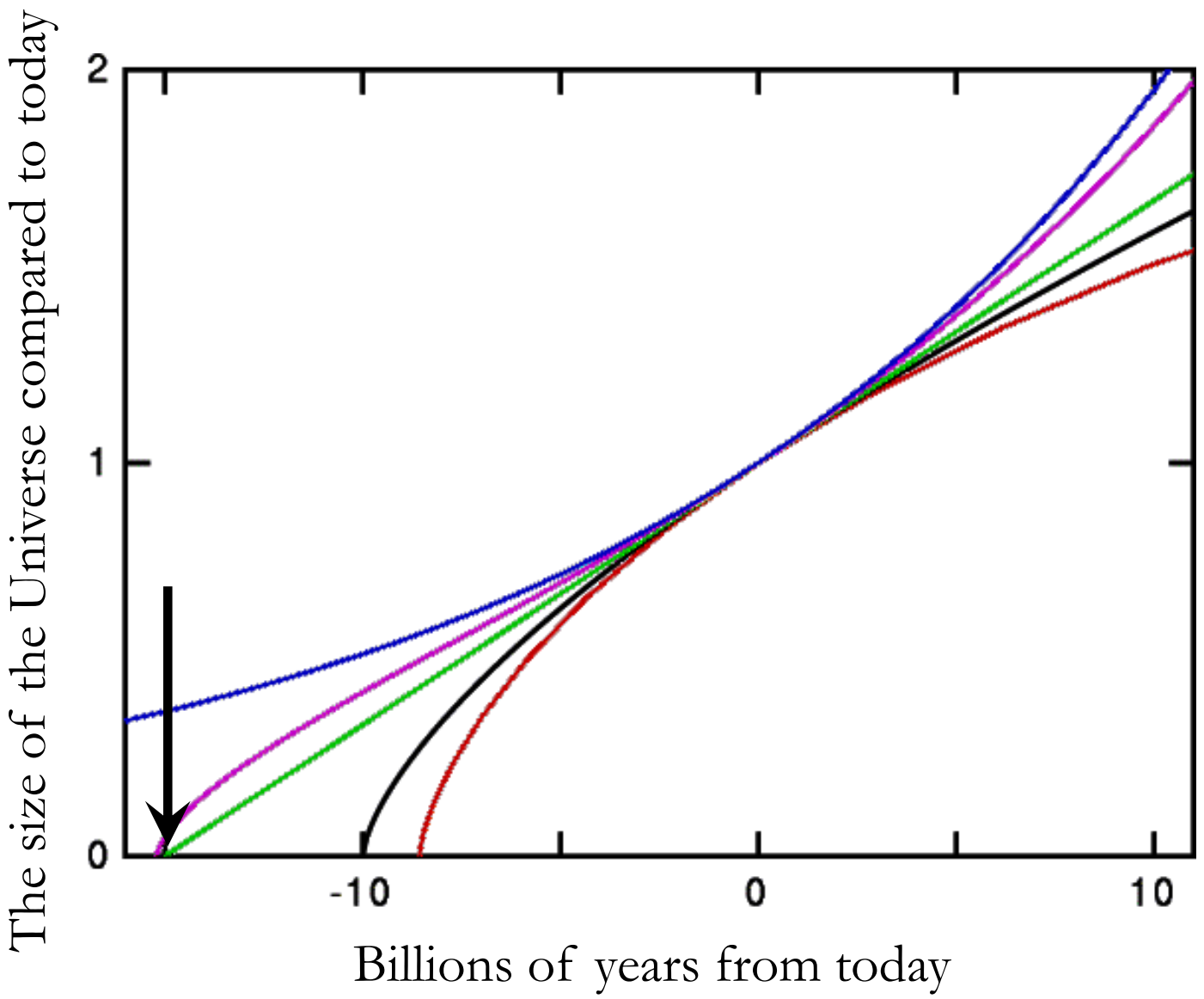
- ❑ The deceleration parameter
- ❑ The acceleration parameter
- ❑ The Hubble constant
- ❑ The spatial curvature

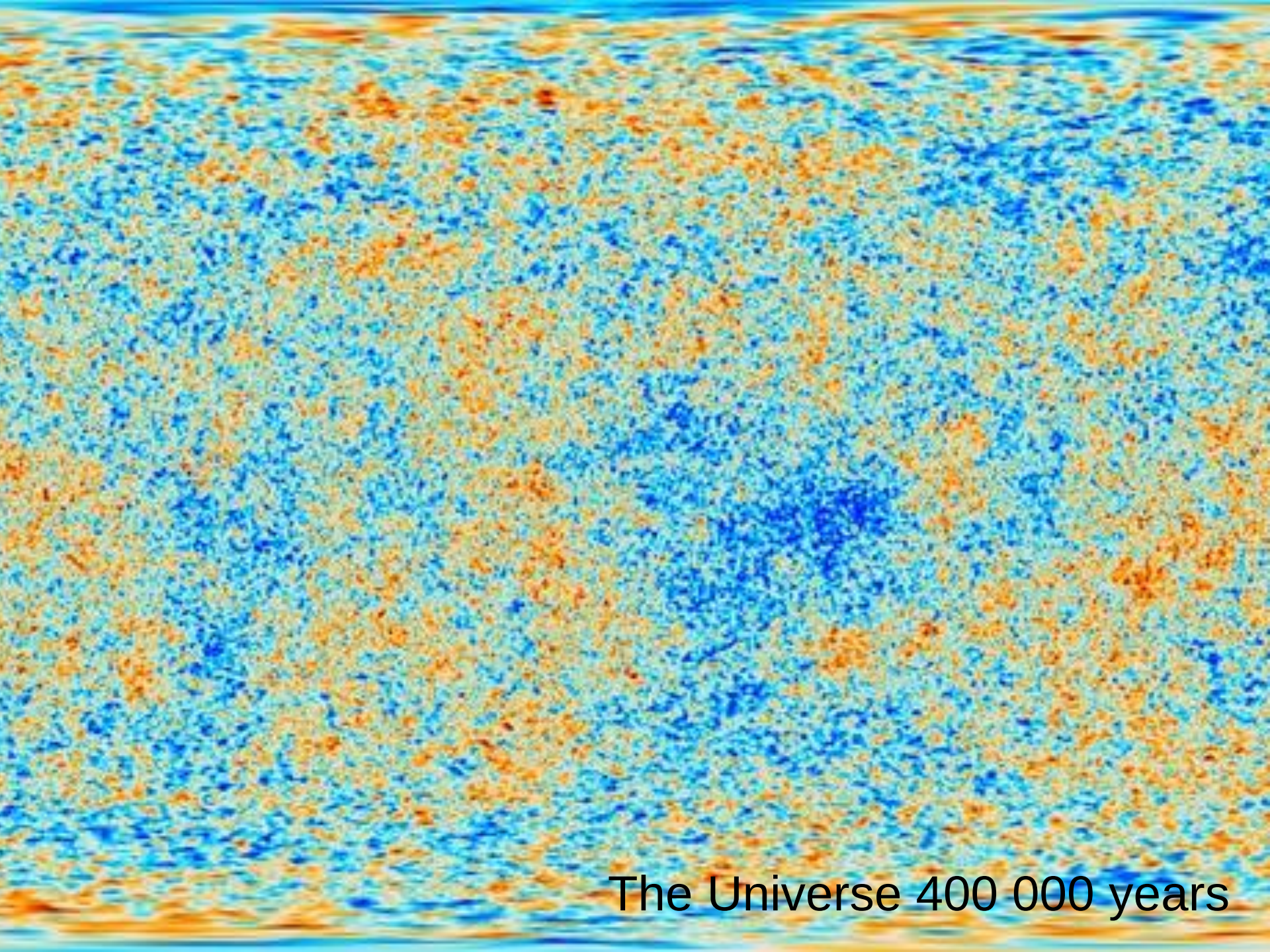




Loa 6 months

The Universe 400 000 years


The size of the Universe compared to today
2
1
0
-10
0
10
Billions of years from today


The Universe 400 000 years

Introduction – Observations and theory

Edvard Mörtsell

Cosmology and Astroparticle Physics FK7050

The Observable Universe

- The expansion of the Universe [1929]
- The discovery of dark matter [1933, 1978]
- The observations of relative abundances of light elements
- The discovery of the cosmic microwave background (CMB) [1965, Nobel prize 1978]
- The discovery of CMB anisotropies [1992, Nobel prize 2006]
- The discovery of the accelerated expansion of the Universe [1998, Nobel prize 2011]
- The measurement of the geometry of the Universe [2000]
- Direct detection of gravitational waves [2016, Nobel prize 2017]

How many of the 206 Nobel laureates in physics are women?

- ❑ 0
- ❑ 4
- ❑ 1
- ❑ 8
- ❑ 2
- ❑ 16

Marie Curie (1903)

Maria Goeppert Mayer (1963)

Theoretical framework

Understand Nature at both *macroscopic* and *microscopic* scales

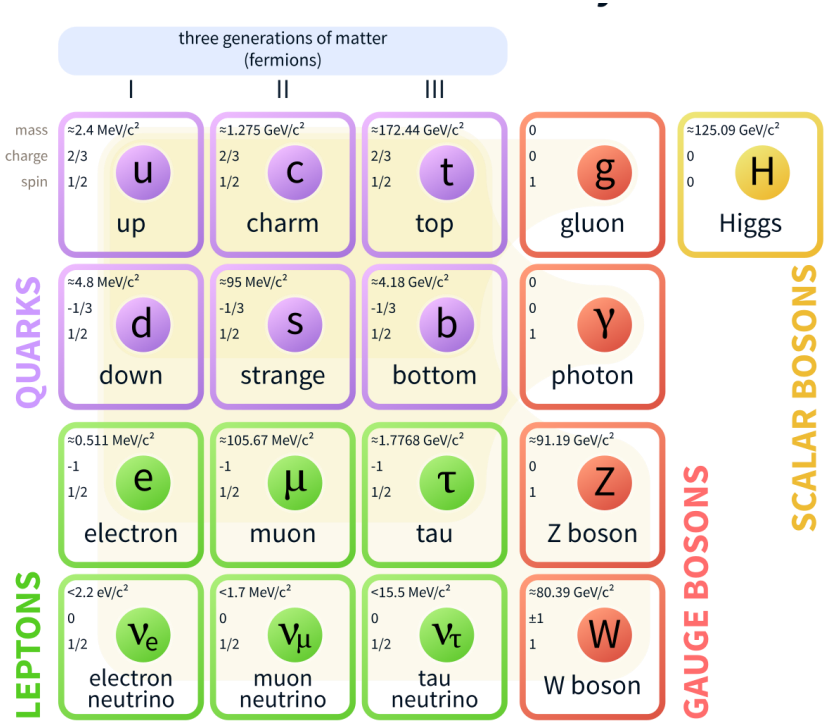
- Gravity on macroscopic scales (General Relativity, GR)
- Electromagnetic, weak and strong interactions on microscopic scales (Quantum Field Theory, QFT)

Gravity and electromagnetism agree with observations to a precision of 10^{-8}

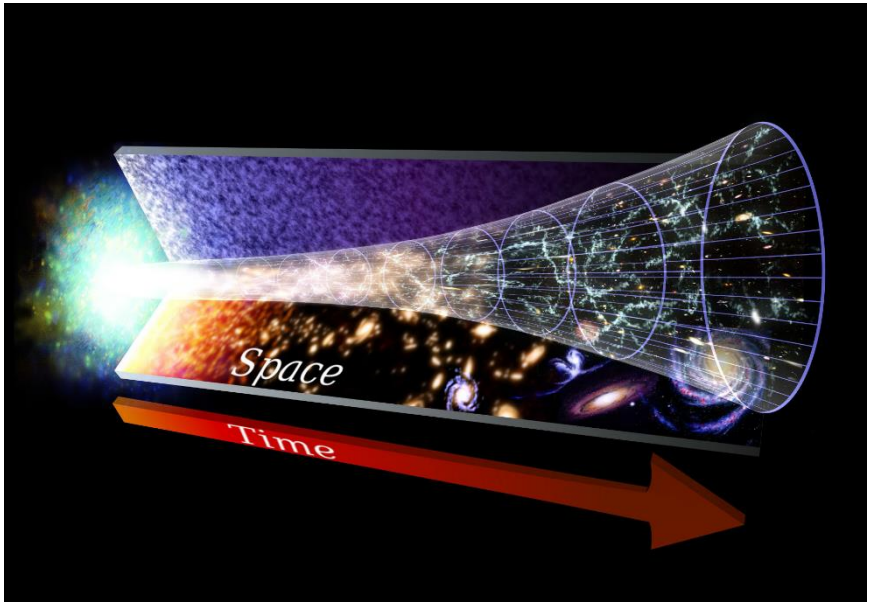
GR and QFT are incompatible and thus incomplete descriptions

Attempts to unify them include loop quantum gravity and string theory

Standard models of Particle physics and Cosmology



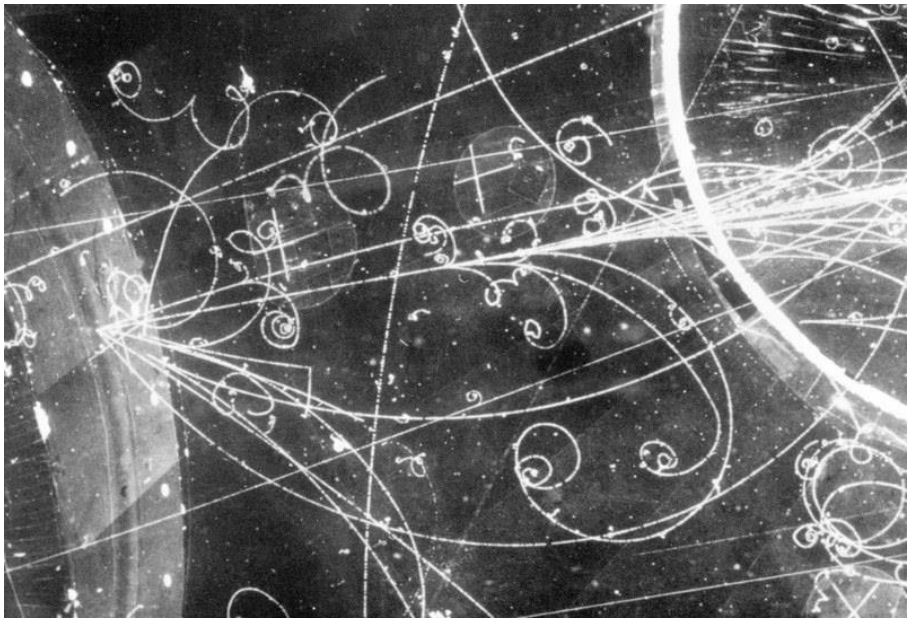
Particle Physics

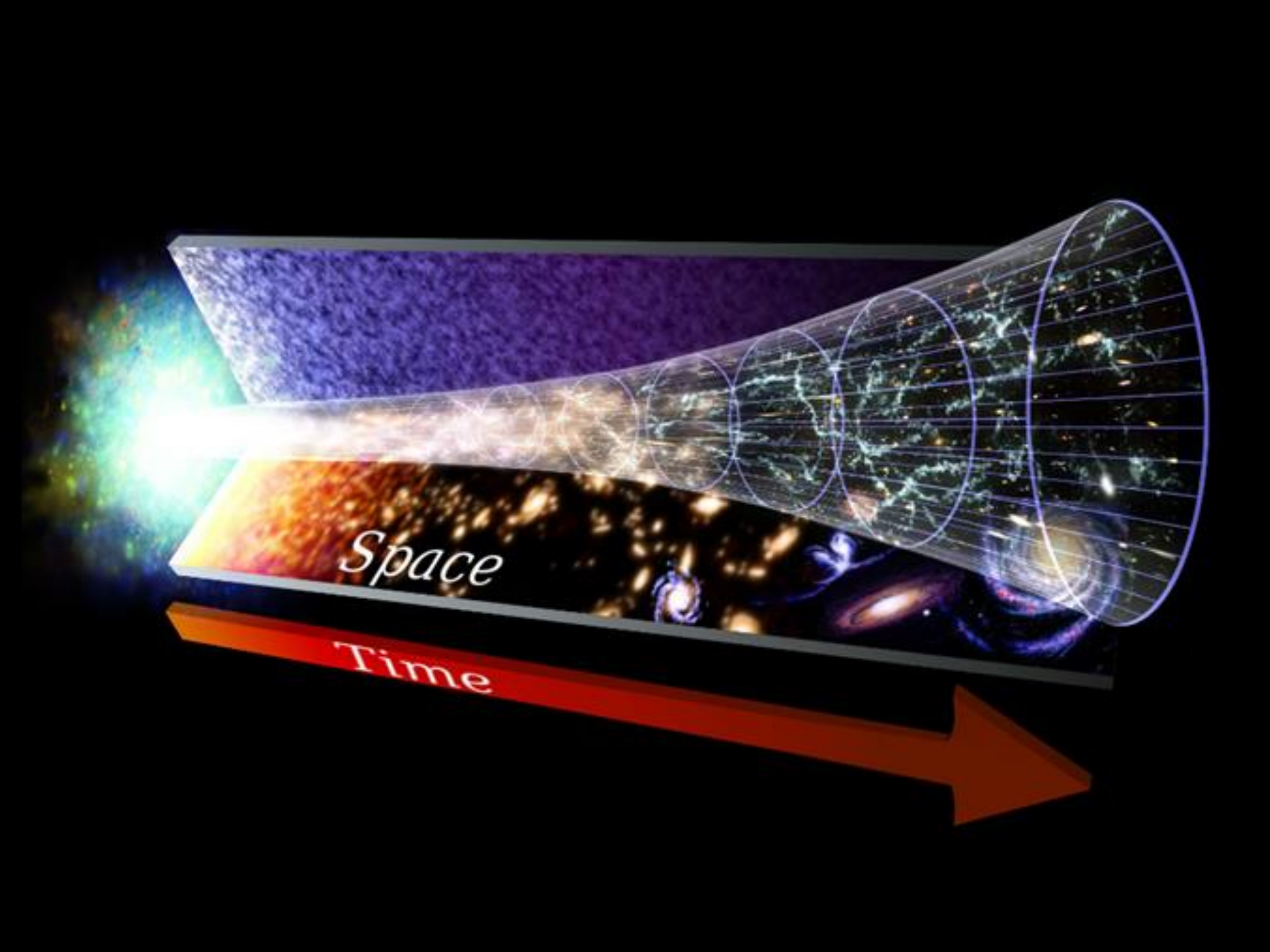


Cosmology

The electron was experimentally verified in the late 19th century. Which particle in the particle standard model was the last to be observationally confirmed?

- ❑ The proton
- ❑ The W boson
- ❑ The Higgs boson
- ❑ The neutralino




Space
Time

Outstanding questions

- How are initial conditions set?
- How did it all begin?
- What determines the laws of Nature?
- What is dark matter?
- What is dark energy?

In the standard model of cosmology, which component is currently dominating in terms of the energy density?

- ❑ Hydrogen
- ❑ CMB photons
- ❑ Dark matter
- ❑ Dark energy