How does Gravity Work ?

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Centre for Theoretical Physics

University of Groningen, The Netherlands

Colloquium

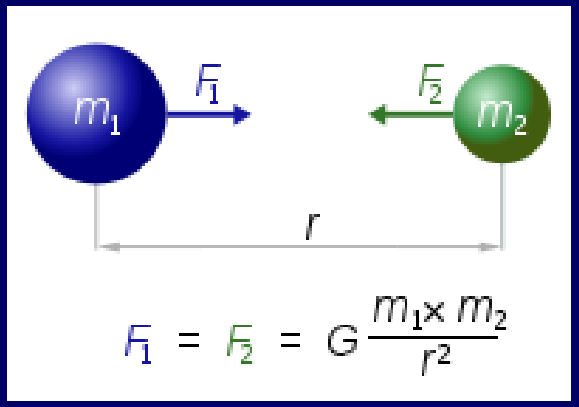
São Paulo, November 6 2013

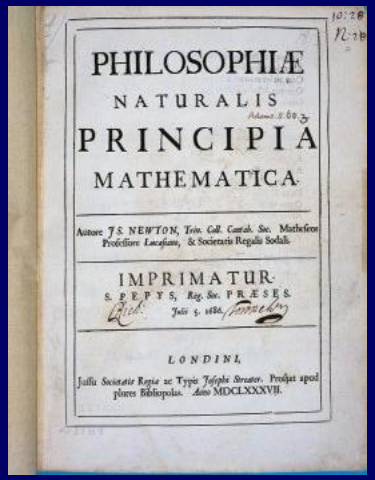
university of groningen

Gravity dominates daily life

gravity at work

gravity according to Newton




PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA

Auctore *IS. NEWTON*, Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.

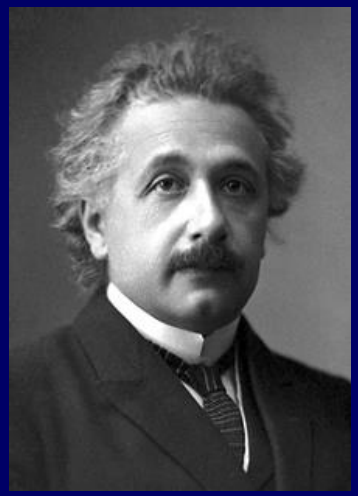
IMPRIMATUR.
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.

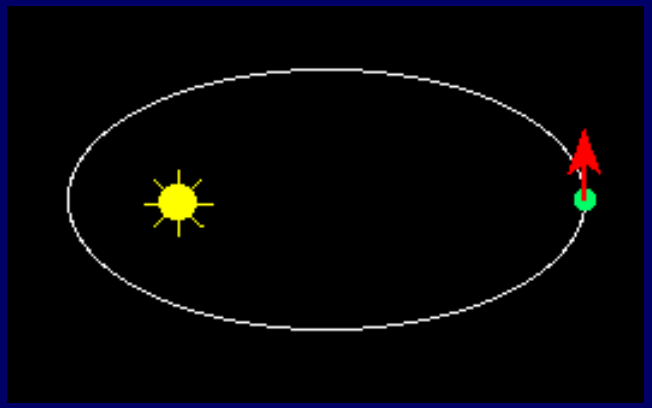
LONDINI,
Jussu Societatis Regiæ ac Typis *Josephi Streater*. Prostat apud plures Bibliopolas. Anno MDCLXXXVII.

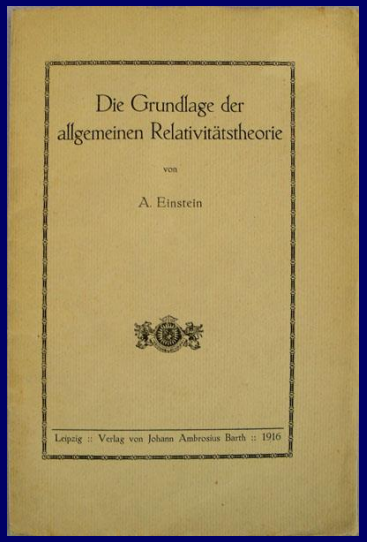
Newton

1687

gravity according to Einstein



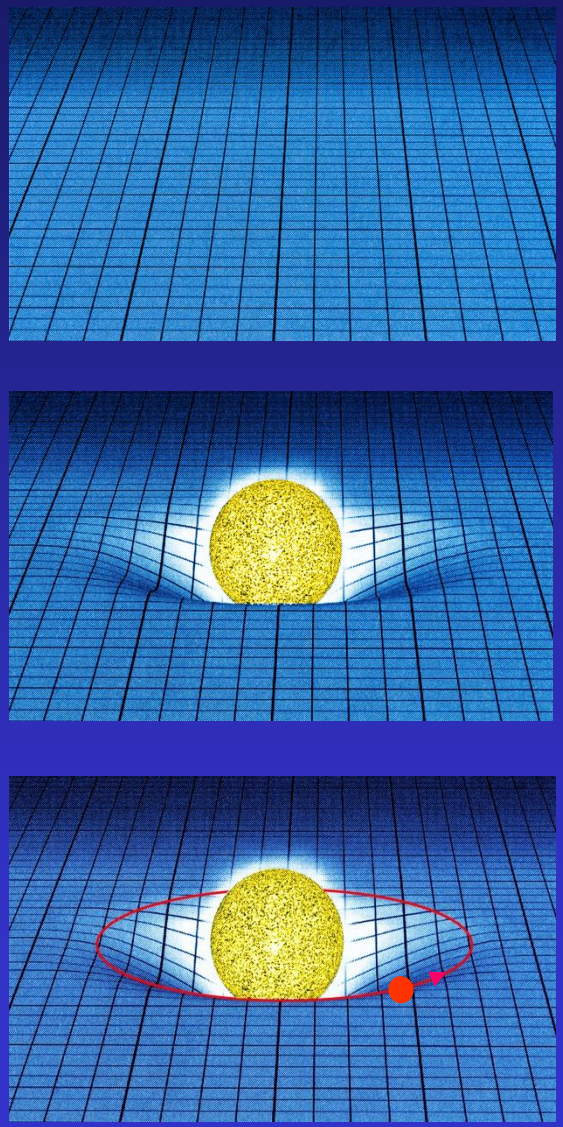




Einstein

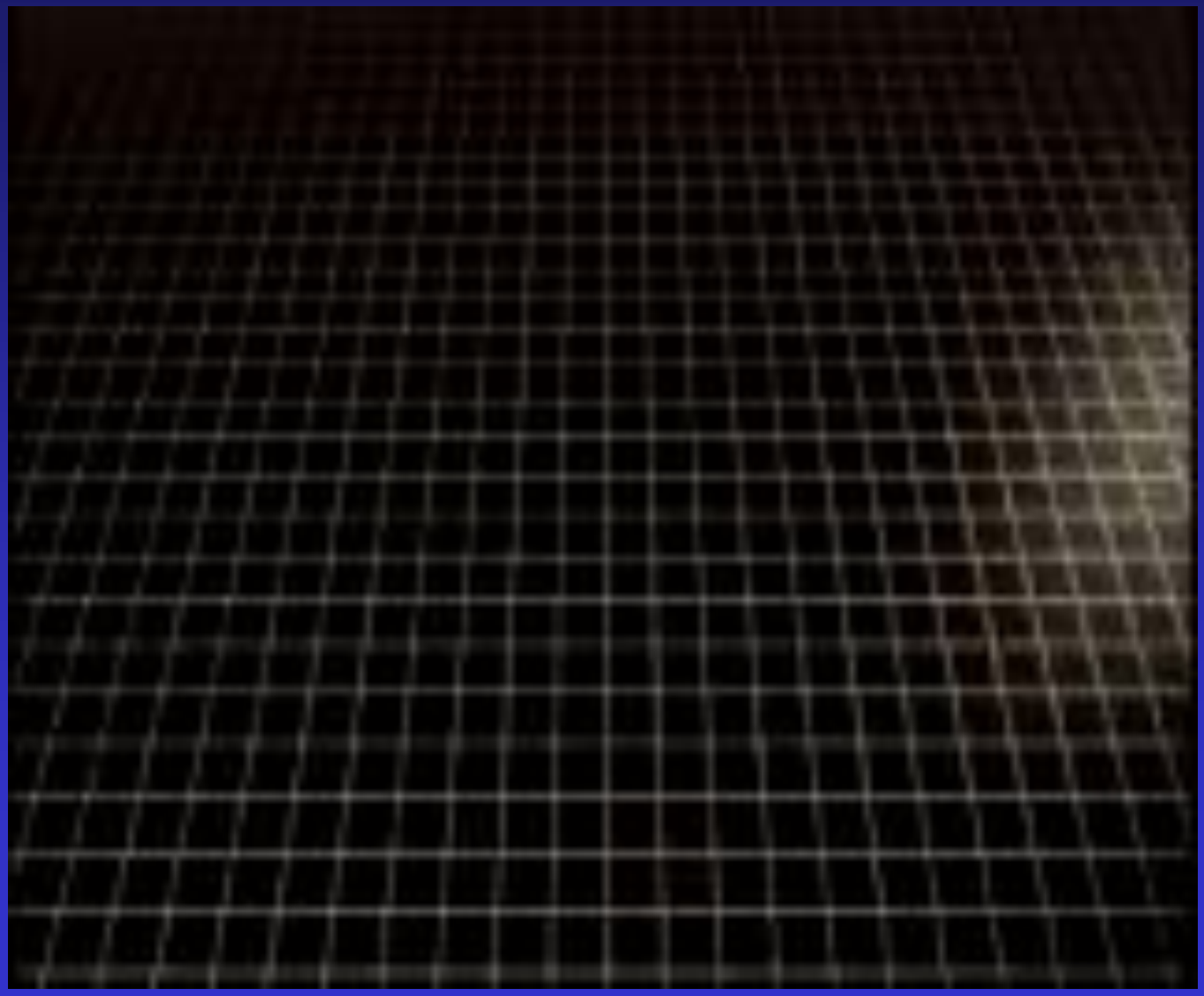
1916

Gravity is a two-step procedure



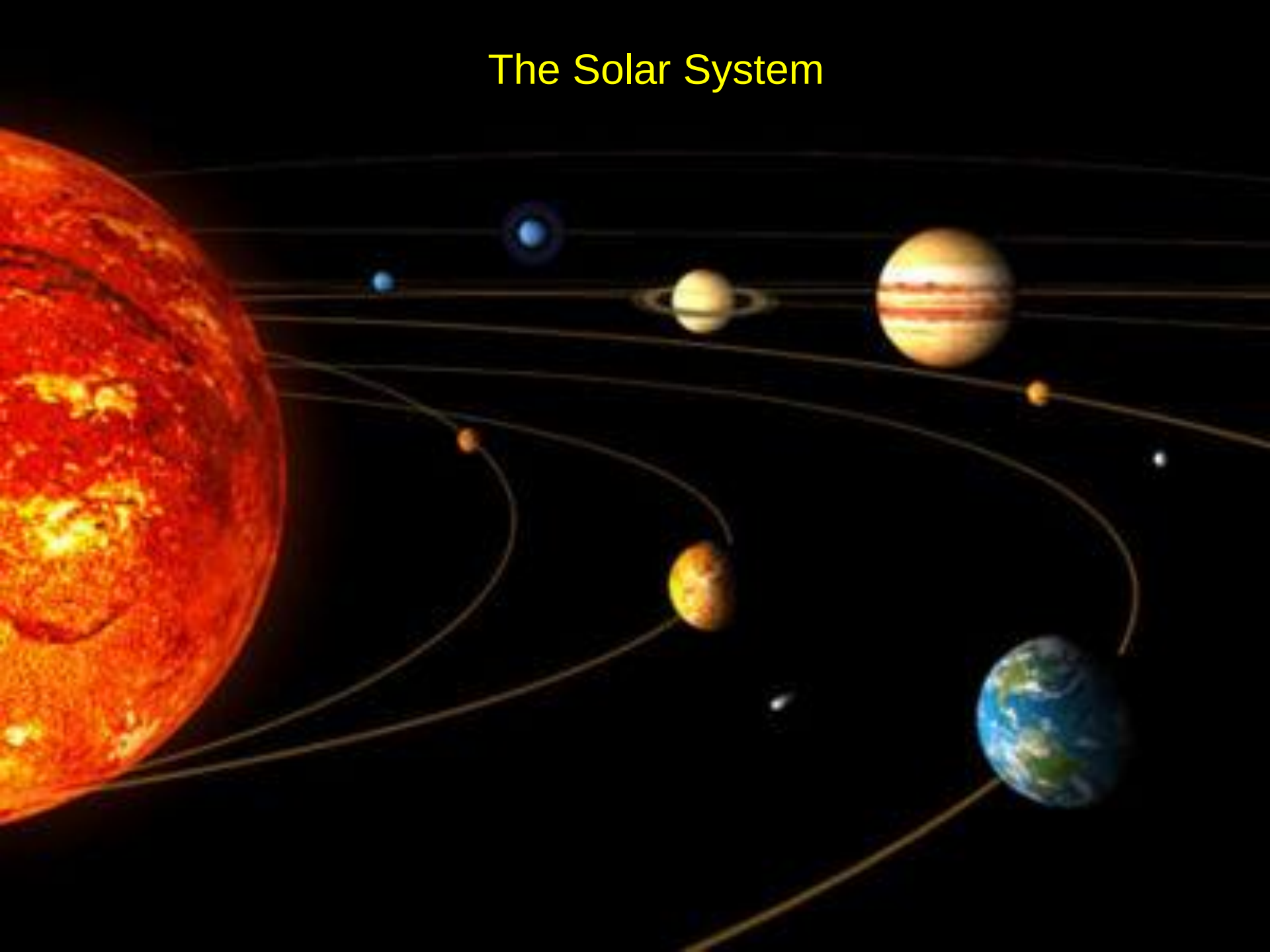
space is curved

simulation



The Earth

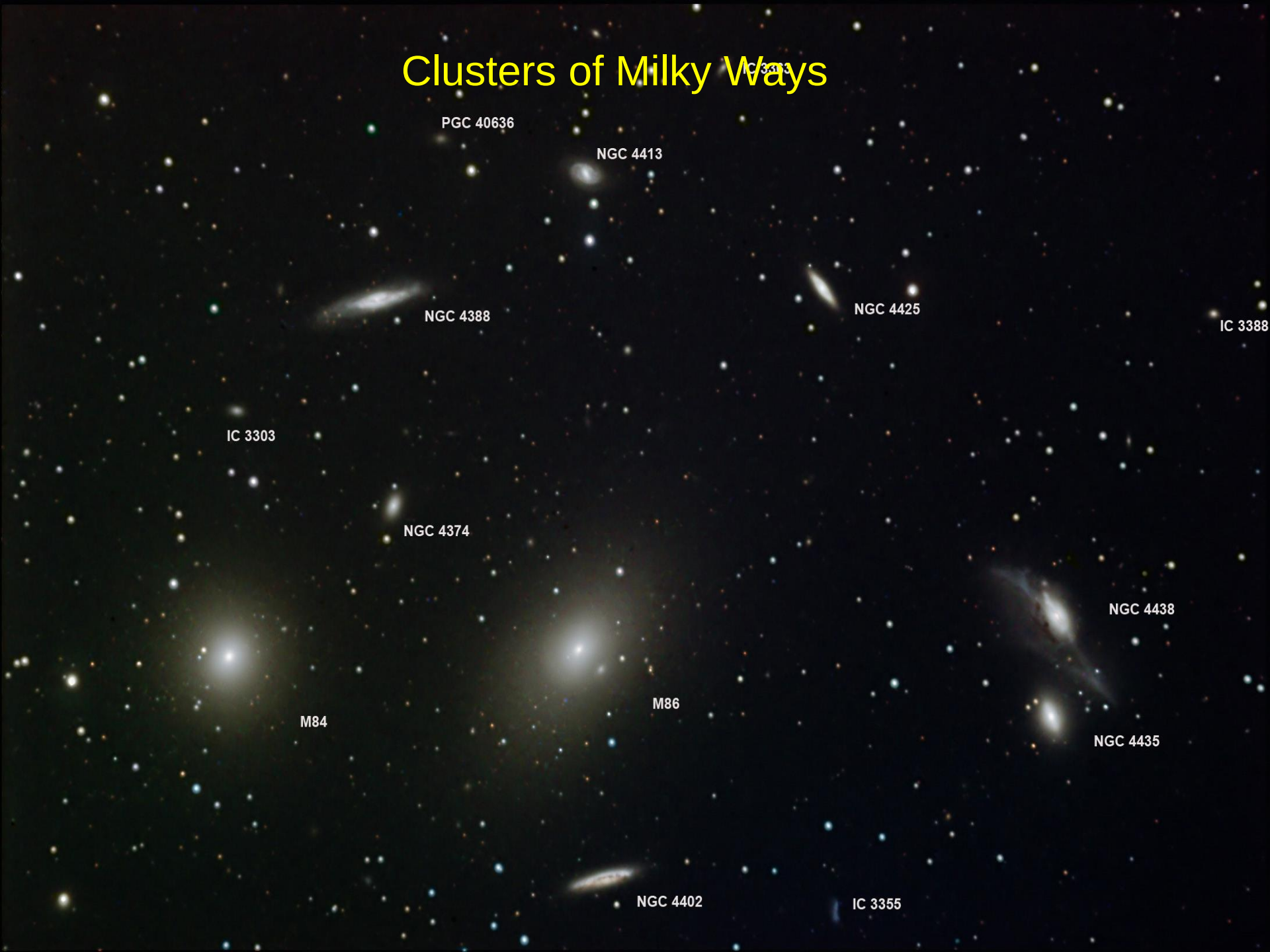
The Solar System

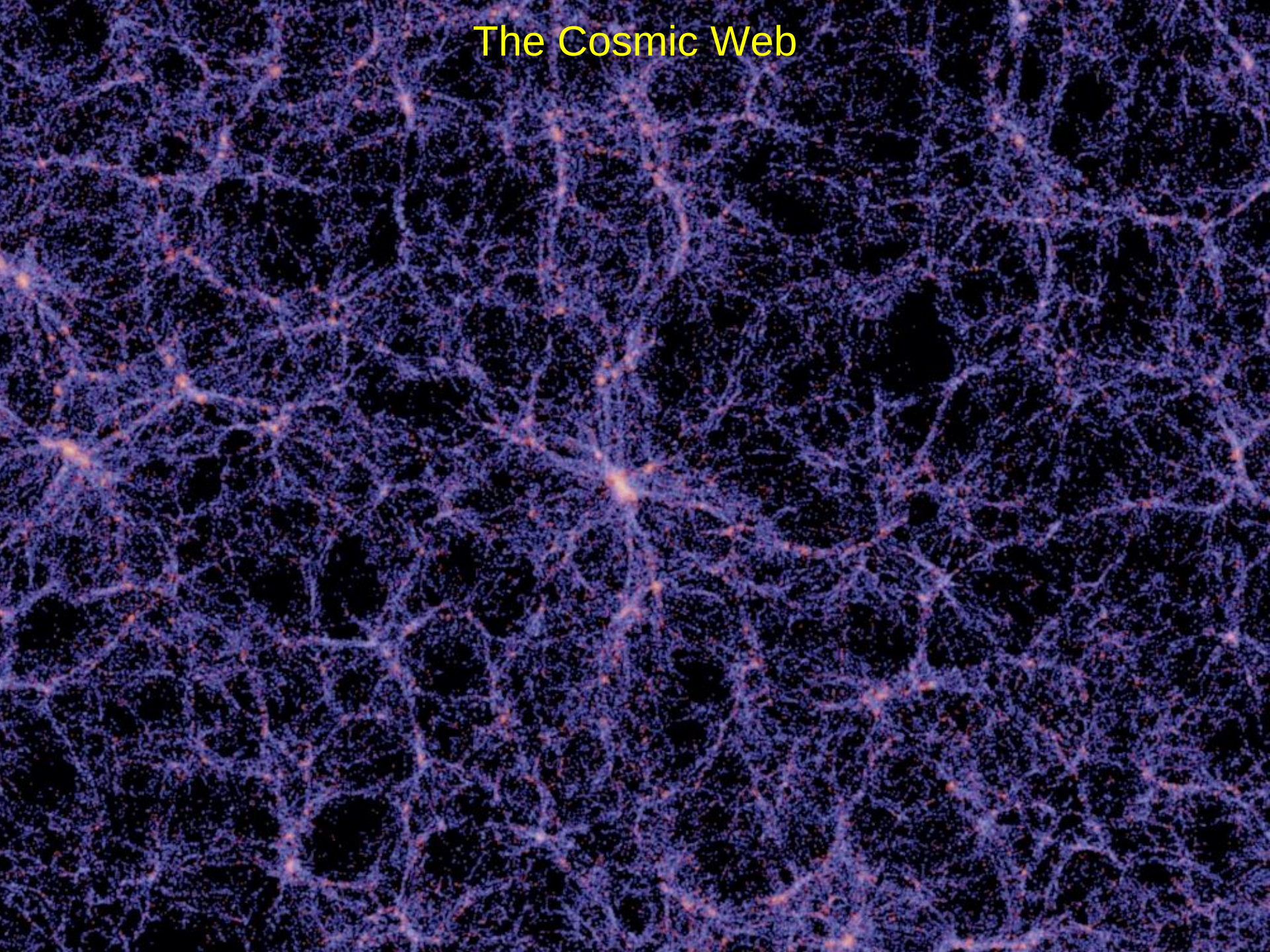


how large is large?


The Milky Way

Clusters of Milky Ways



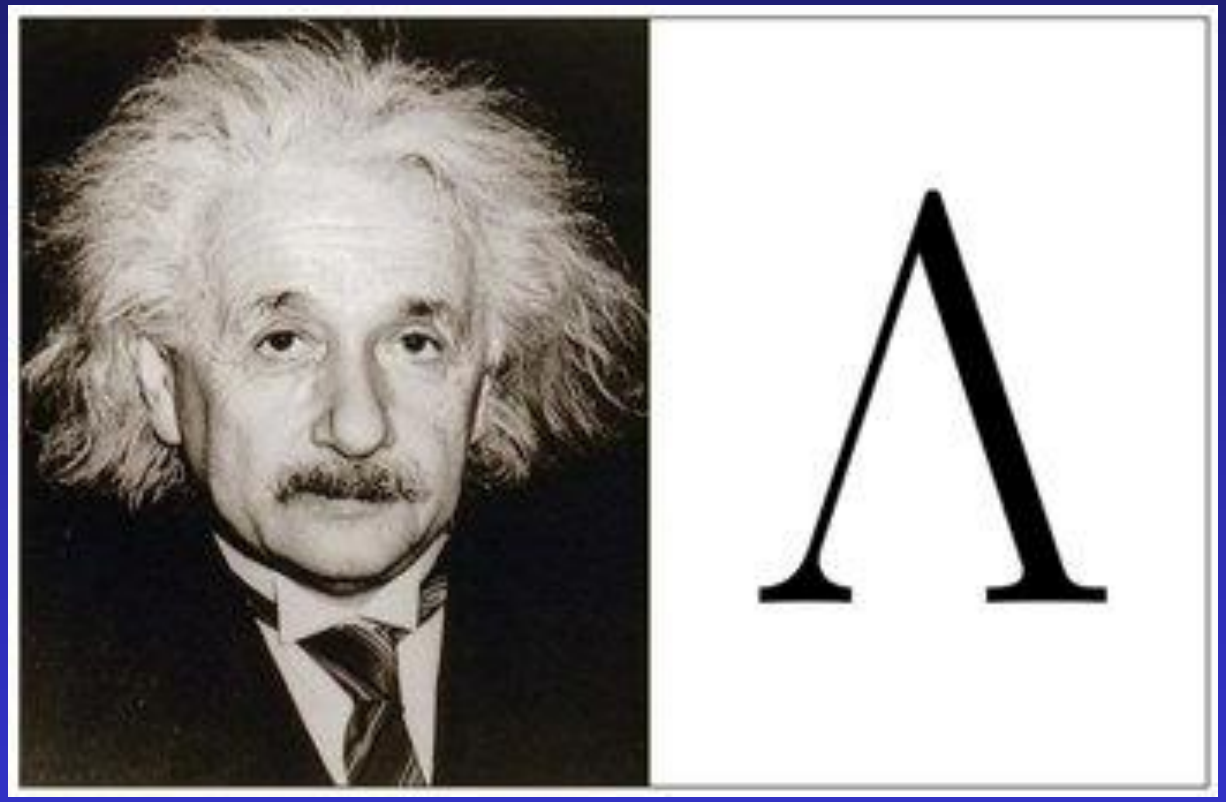

The Cosmic Web

Gravity determines the physics

at large distances

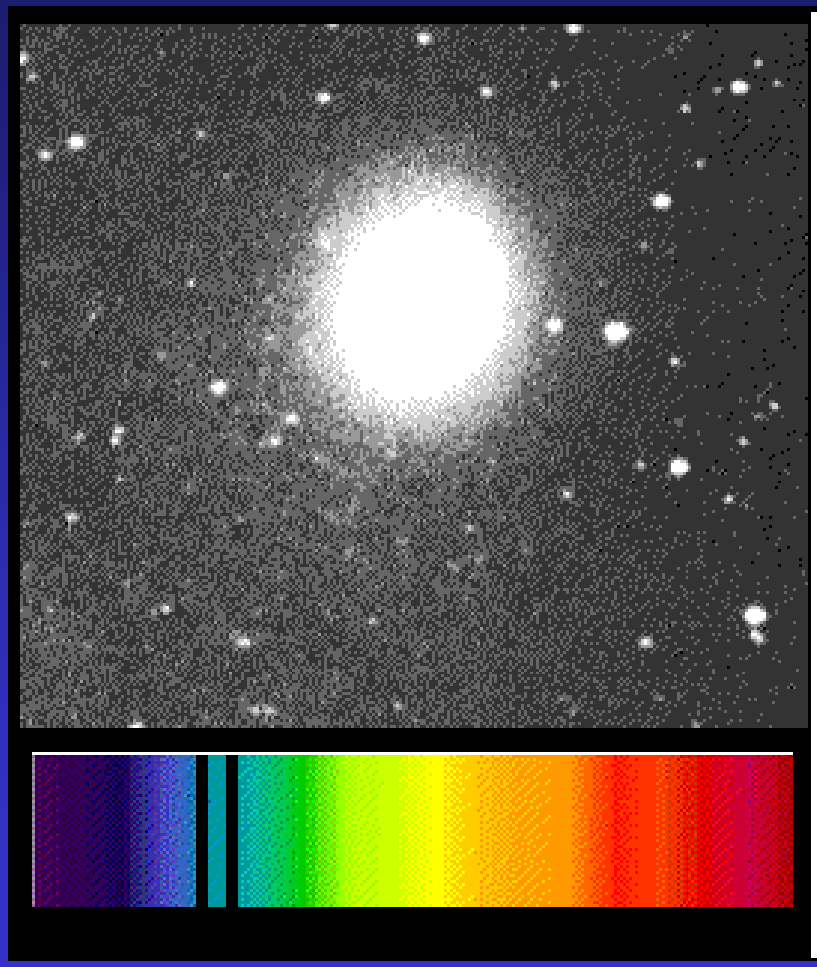
there are, however, a few problems….

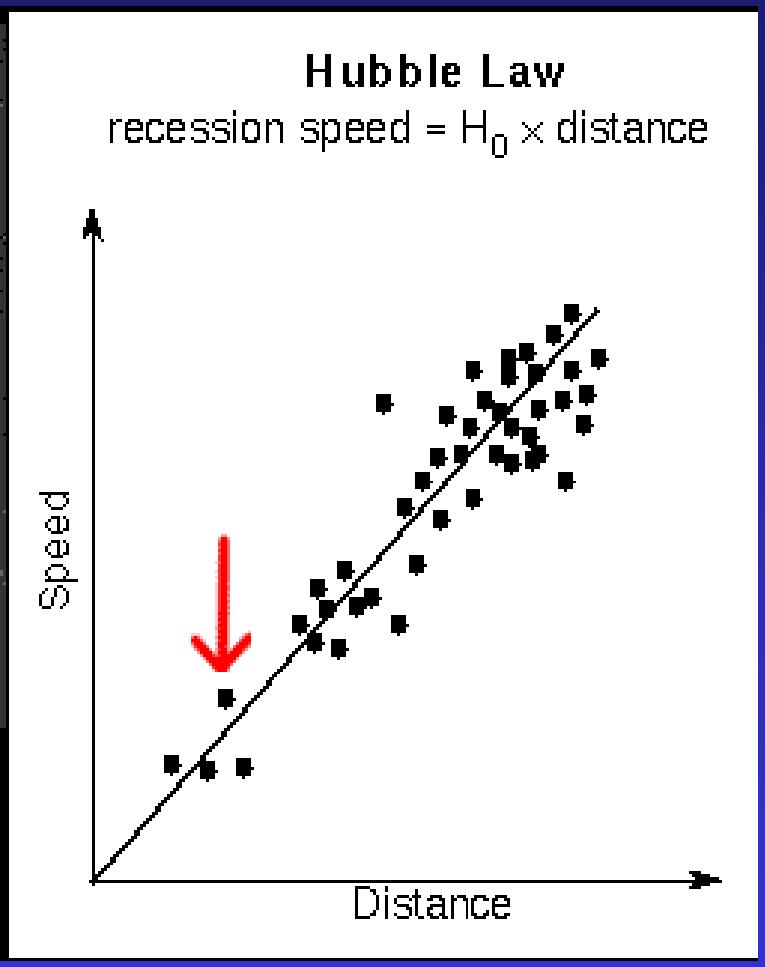
The Cosmological Constant



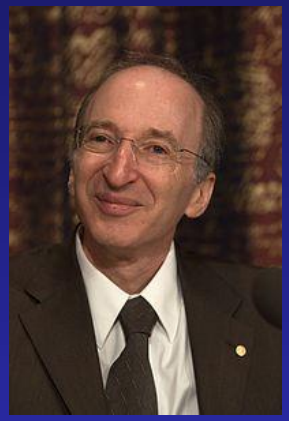
the Universe is not static!

Hubble's Law (1929)



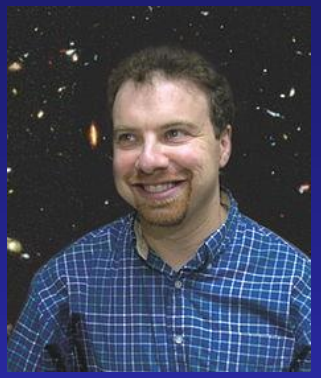


1998



Perlmutter

Schmidt



Riess

the universe is *accelerated* expanding!

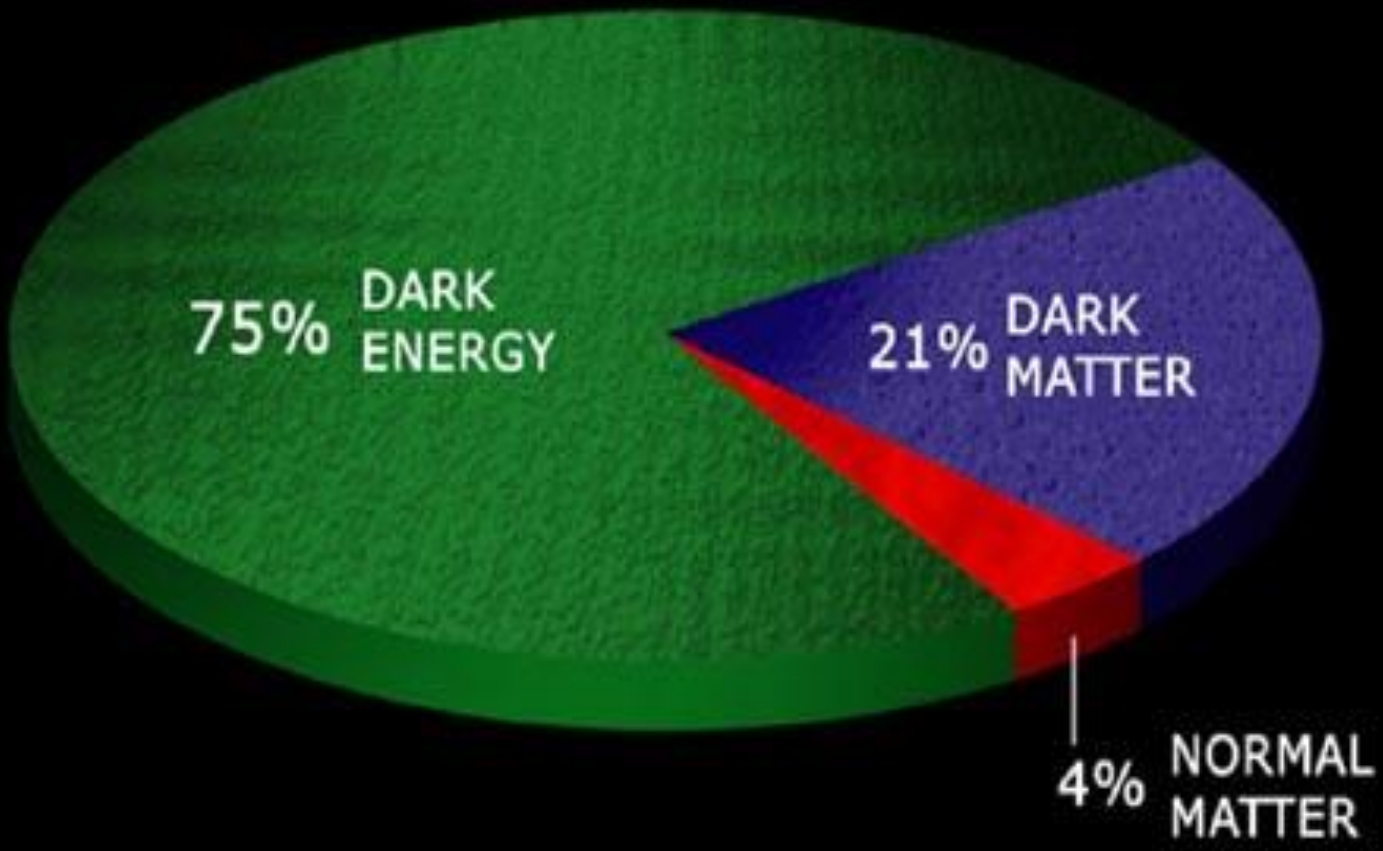
The theoretical prediction does not agree

with the experimental observation !

by a factor of 10^{-120}

the worst theoretical prediction in the history of physics!

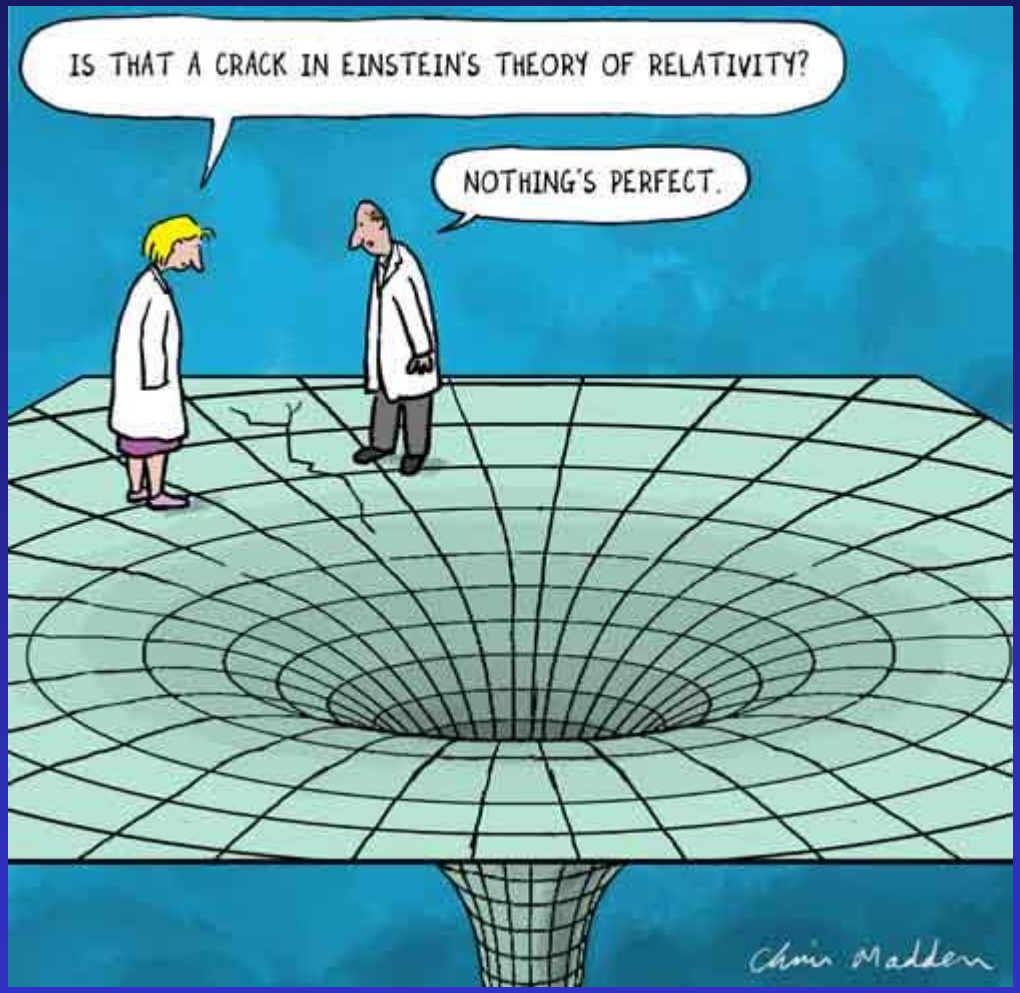
Dark Energy



Can Einstein's theory be modified

at large distances ?

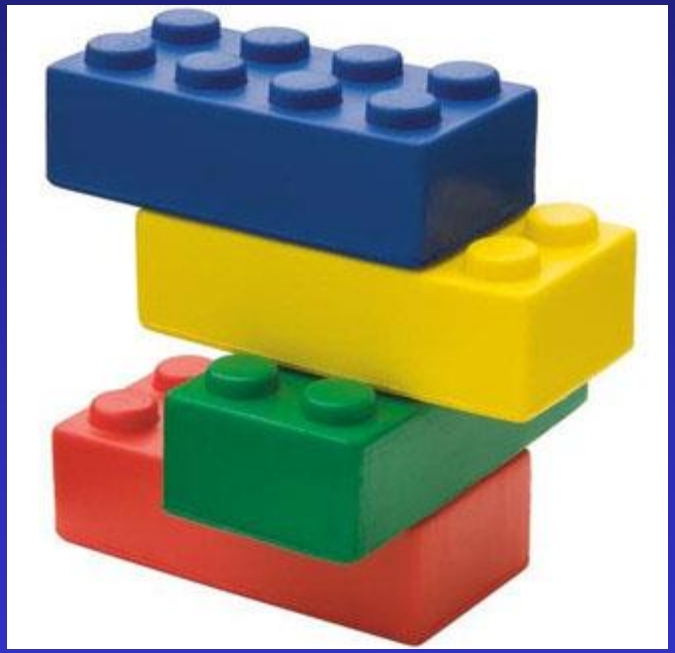
(`DGP model', `dRGT gravity', etc.)



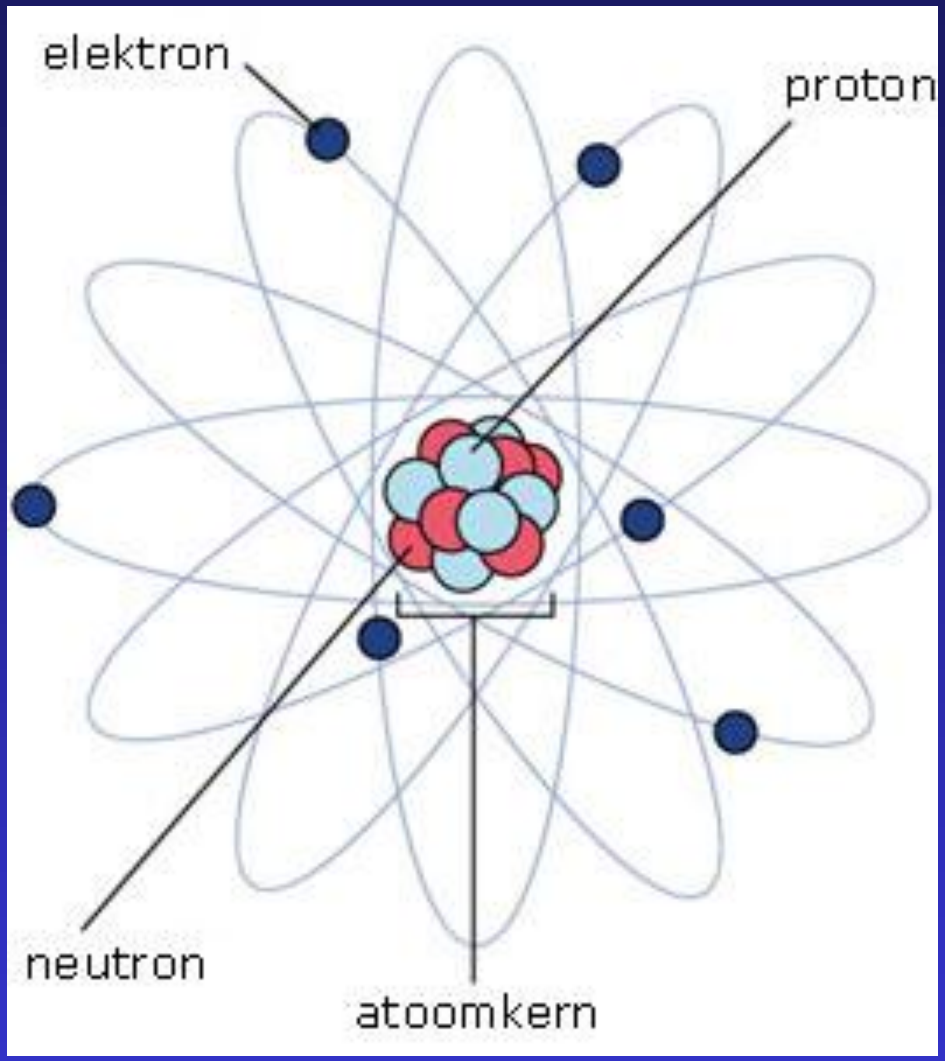
It is not easy to modify Einstein !

What about small distances ?

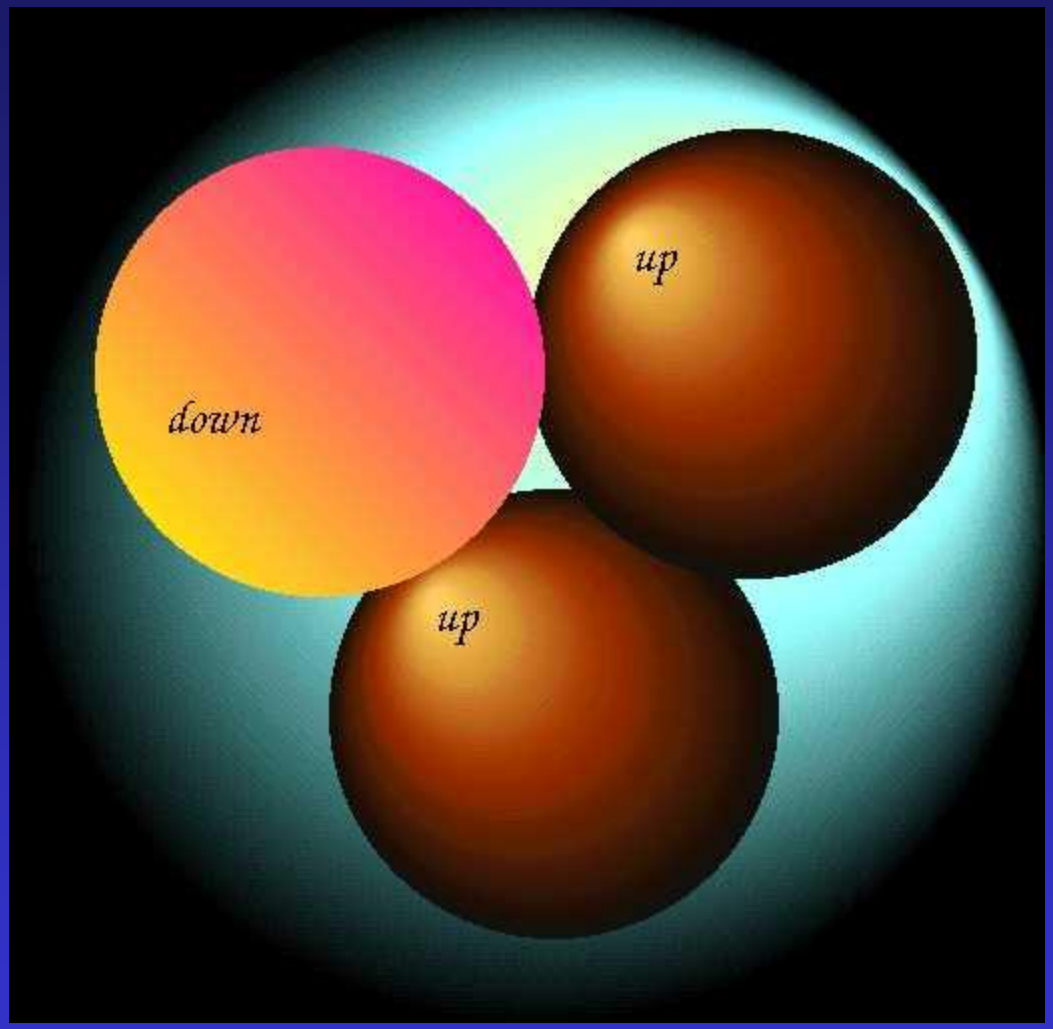
What are the smallest building blocks?



How small can you go ?

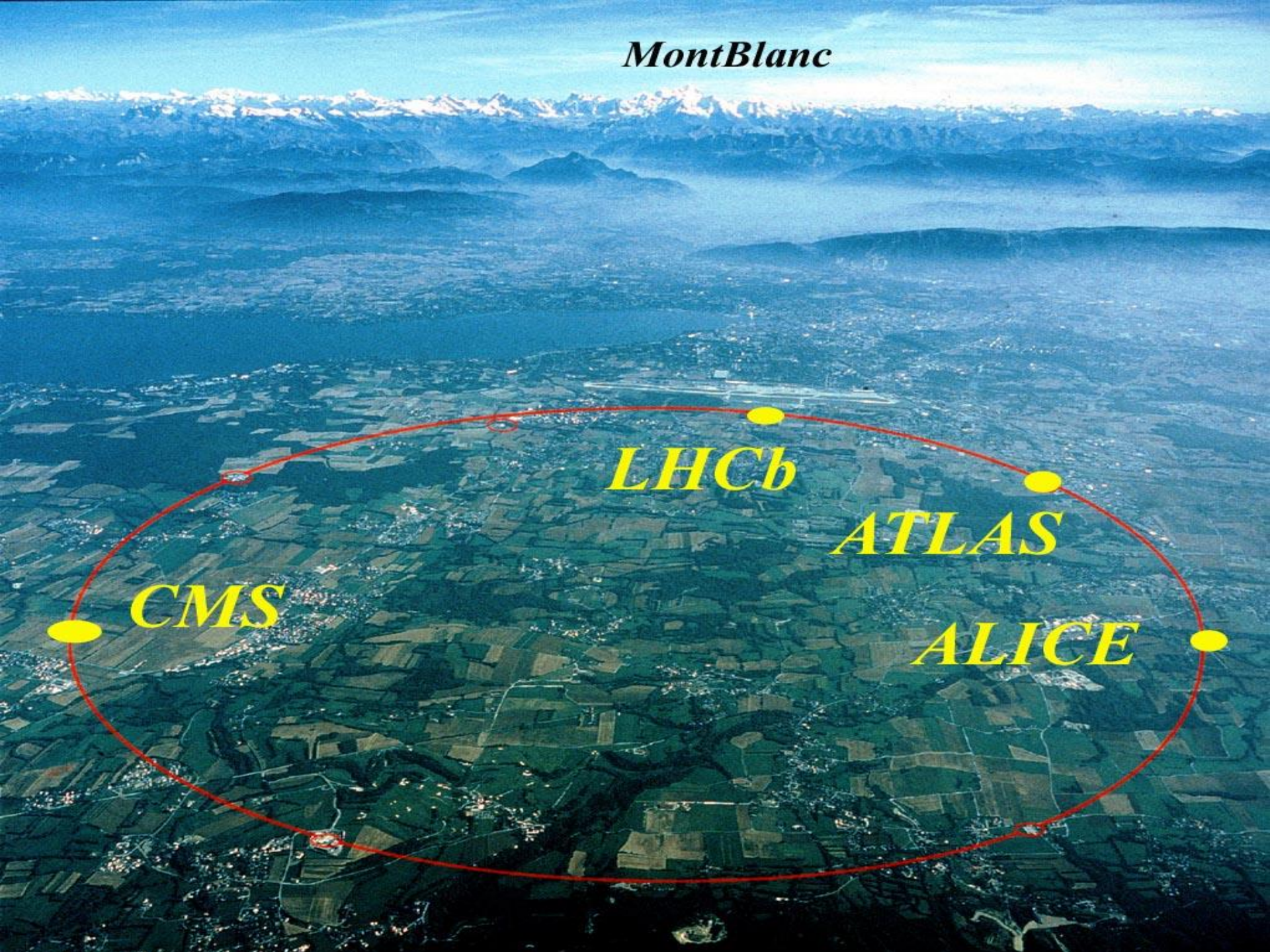


the atom

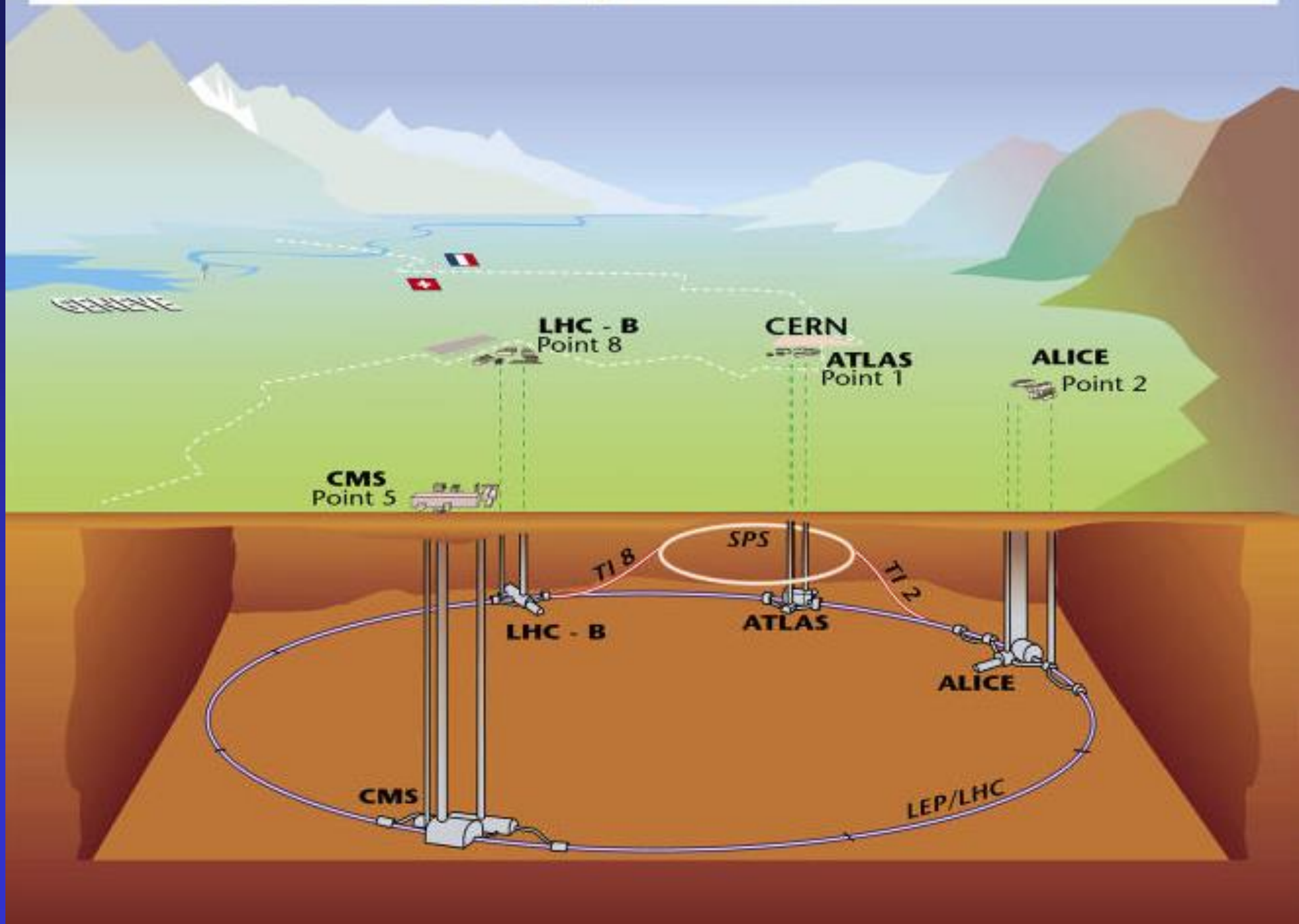


the proton

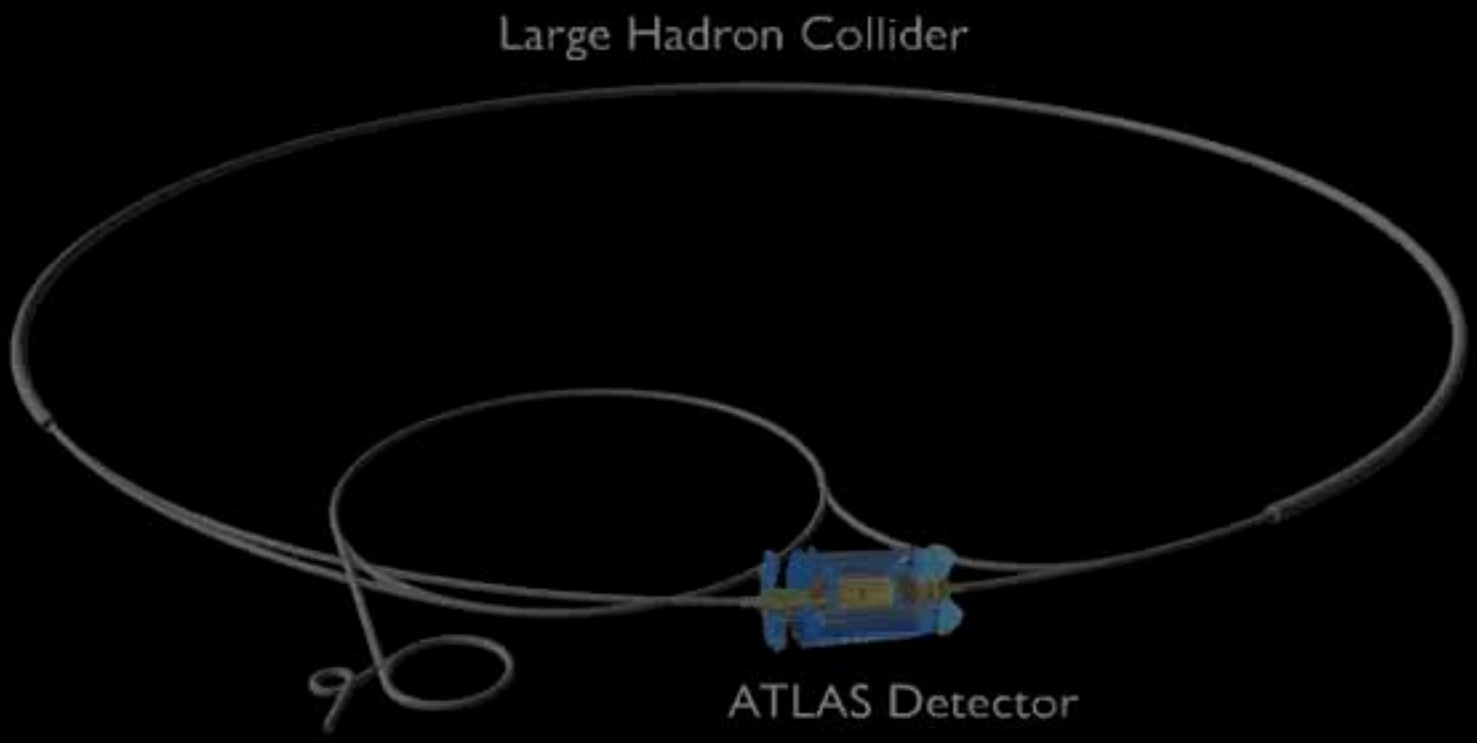
The Experiment

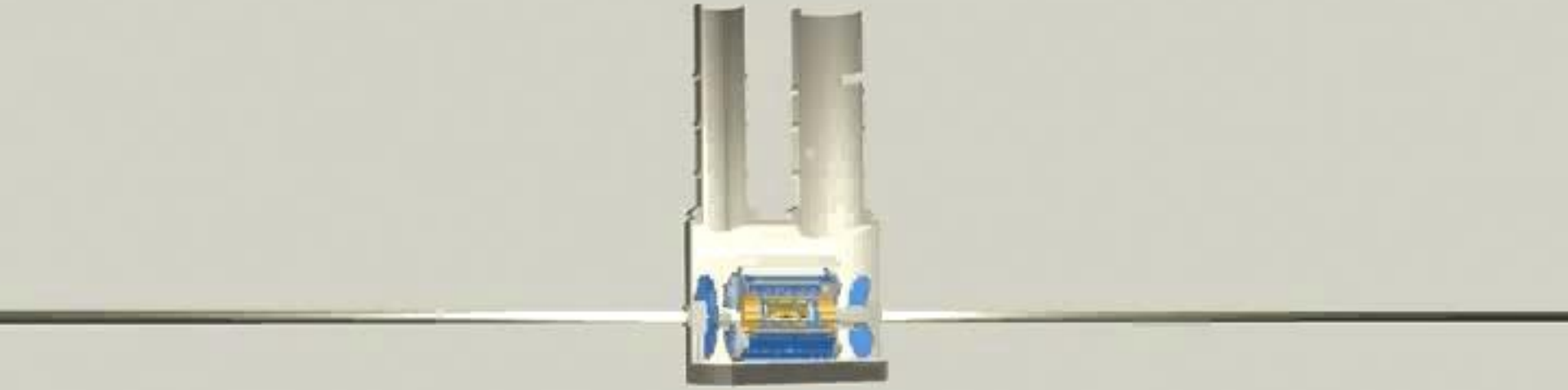

MontBlanc
LHCb
ATLAS
CMS
ALICE

Overall view of the LHC experiments.

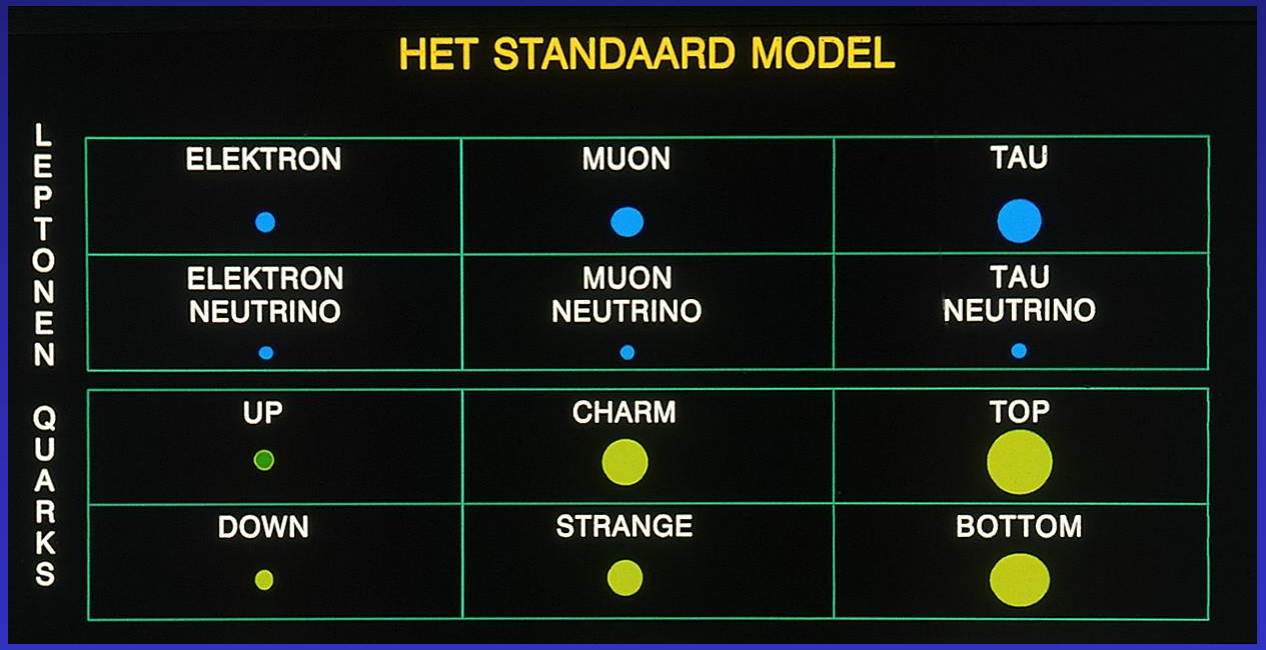


PLAY



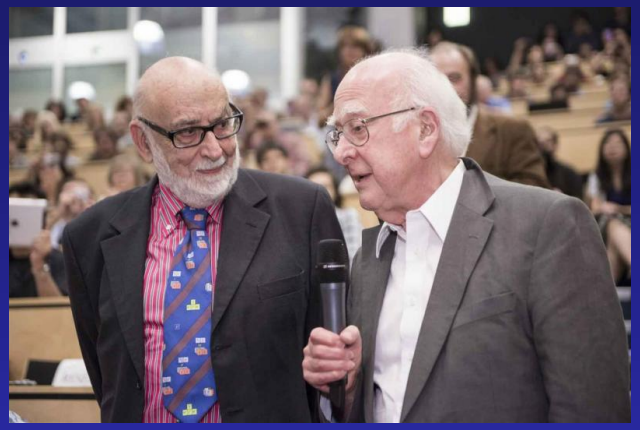


The smallest building blocks



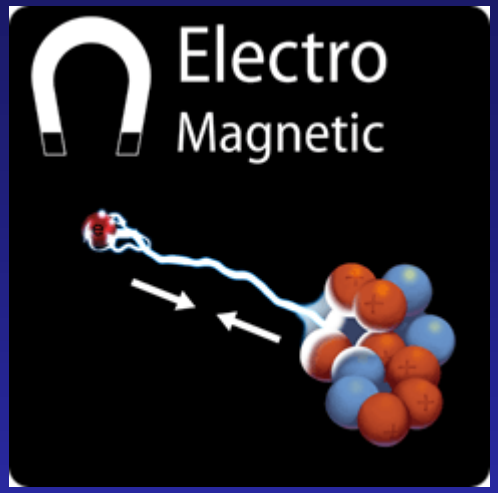
(plus `force-carrying particles')

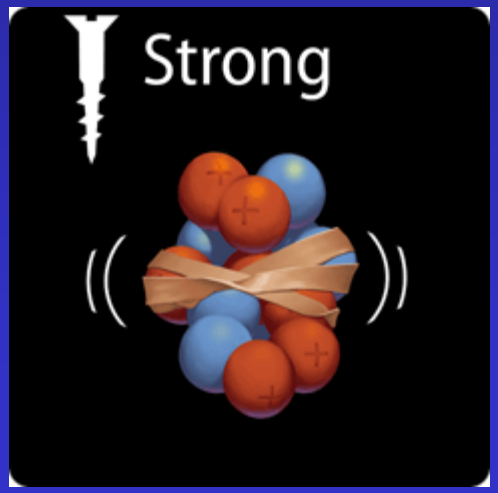
plus the Higgs particle !



Nobel Prize 2013

Three Forces





Gravity does not play any role

at small distances

Quantum Mechanics determines the

physics at small distances

*Quantum*mechanics

without quantum mechanics

everything would fall apart !

the rules of quantum mechanics

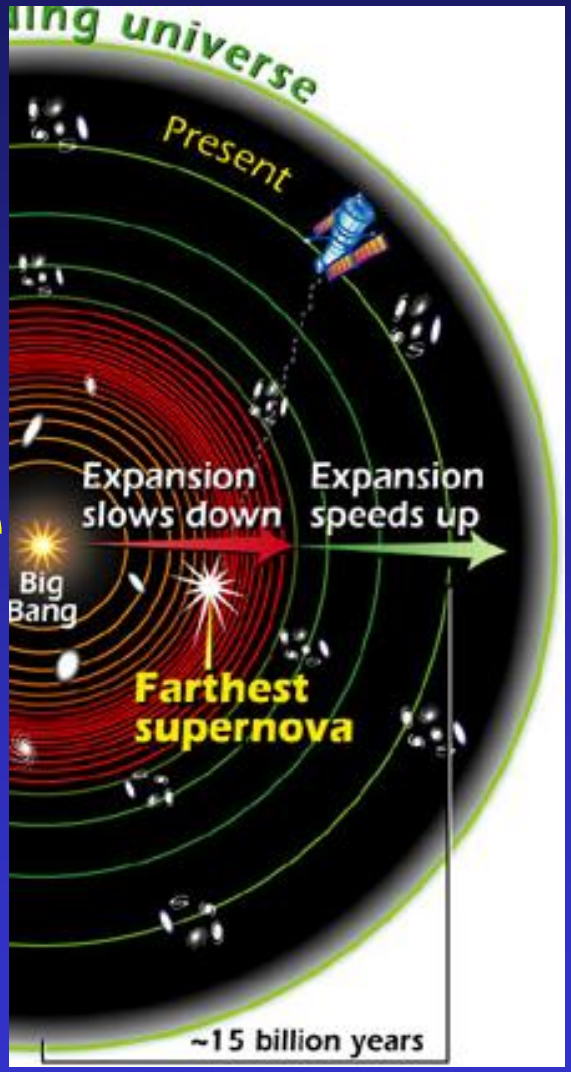
cannot be applied to gravity !

is this a problem ?

we live in an expanding universe!

Hubble (1929)

ne


ing universe
Present
Expansion slows down
Expansion speeds up
Big Bang
Farthest supernova
~15 billion years


The Big Bang

Quantum Gravity is the dream marriage

between quantummechanics and gravity


howcanquantumgra
vityhelpexplaintheo
riginoftheuniverse?

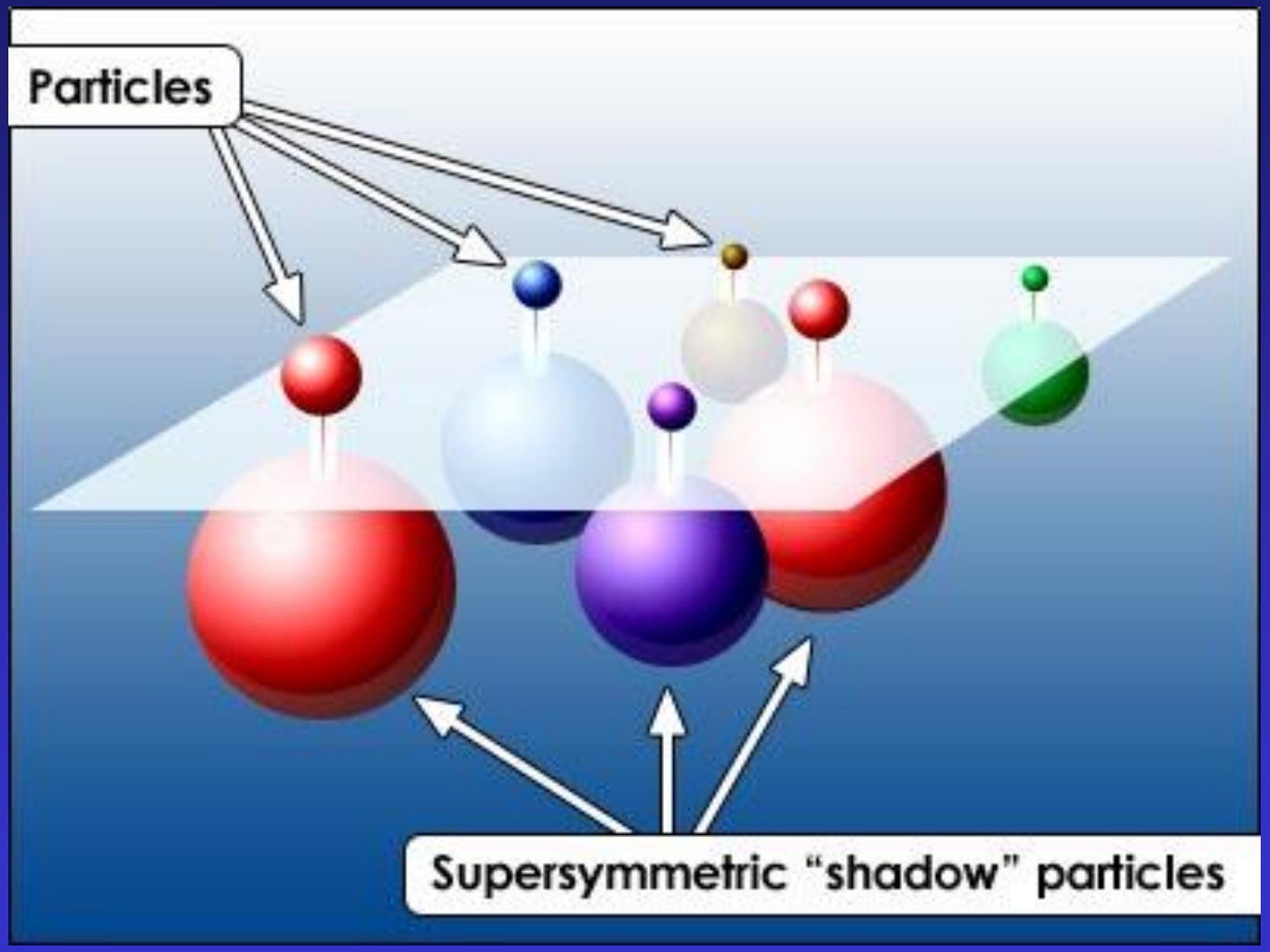
How do we solve the problem of

Quantum Gravity ?

One approach:

Use more *symmetries*

Supersymmetry (70's)




SUPER
GRAVITY
(80's)

Supergravity is not complete!

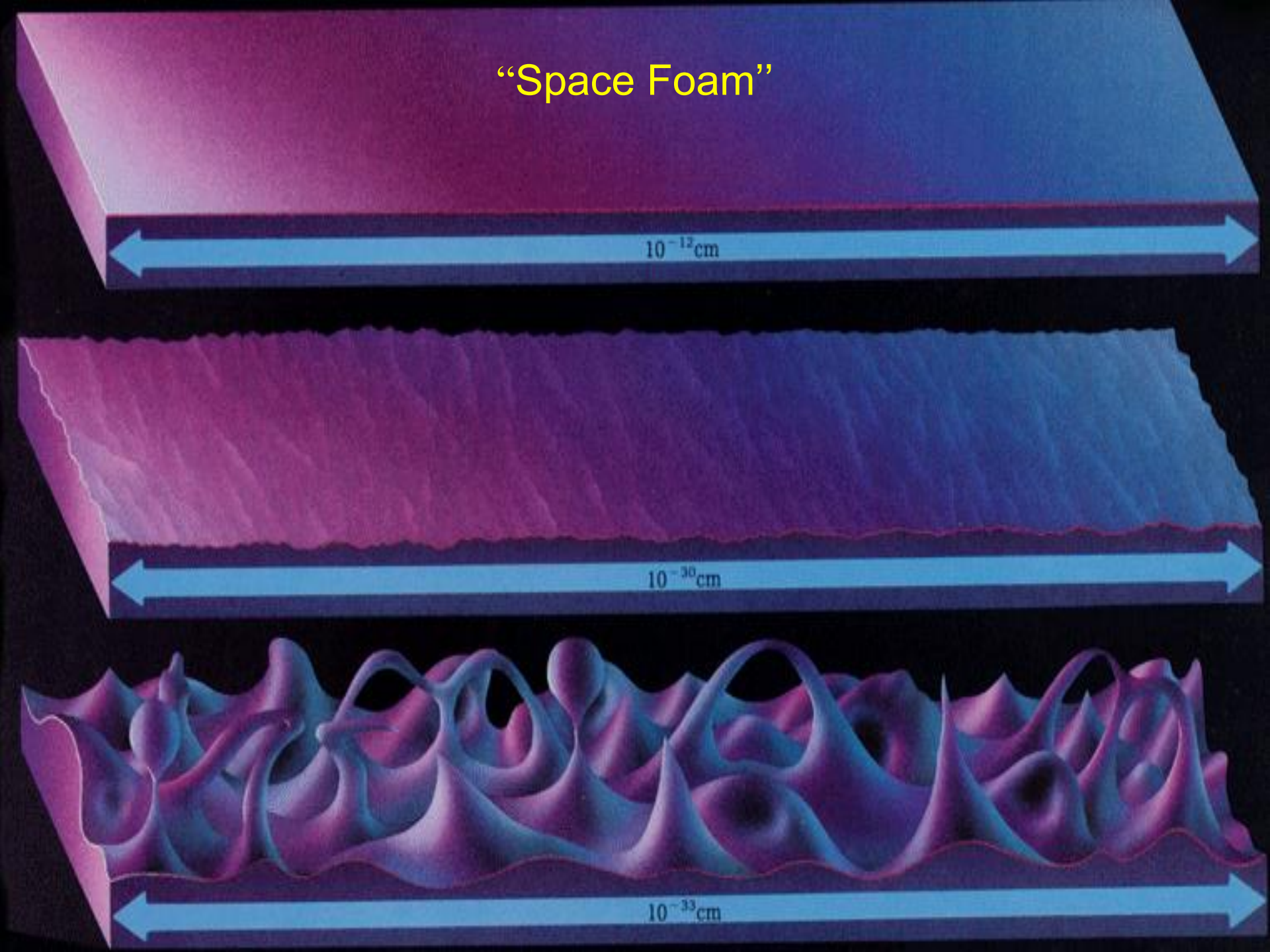
(mixed-symmetry tensors?)

Supergravity is not good enough

(we think …)

The string theory proposal

What is Space ?


"Space Foam"
10^{-12}cm
10^{-30}cm
10^{-33}cm

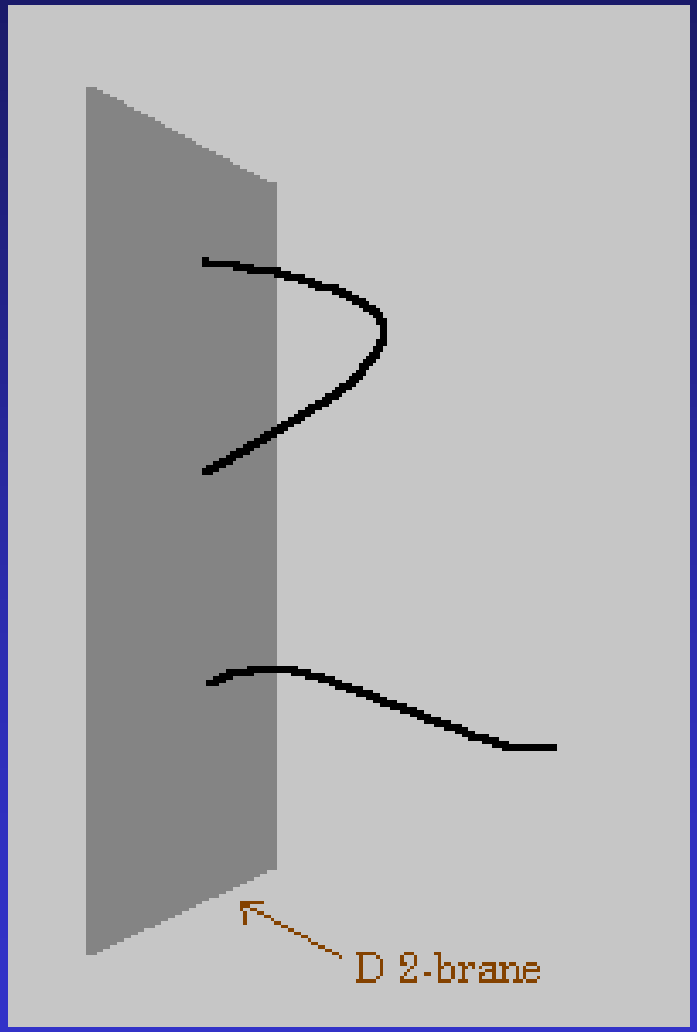
String Theory

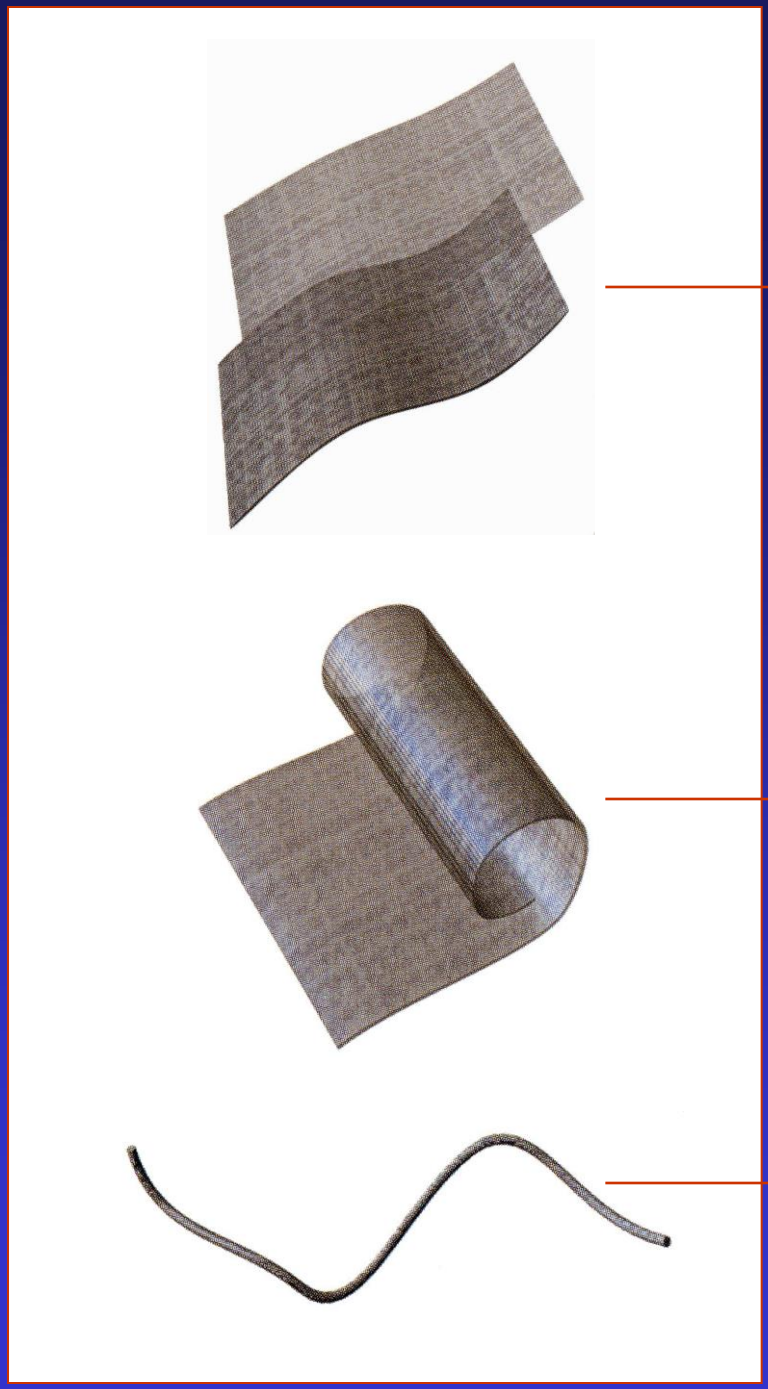
From Strings

to `Branes' (1986)

From Branes

To `Dirichlet Branes' (1995)


D 2-brane


1
2
3

"*The theory formerly known as strings*"

Scientific American, February 1998

What is the present situation ?

Unanswered questions

in Gravity

- large distances: dark energy?

- small distances: quantum gravity?

Holography

A problem in gravity can be mapped

to a problem in CFT

in one dimension less

"*Unity in Diversity*"

What do the theoreticians do?

What do the theoreticians do?

at the workshop on

`Higher-Spin and Higher-Curvature Gravity'

Trying to understand the limits

of the `AdS/CFT correspondence'

- What happens if you go beyond spin-2?
- Replace AdS by flat space
- What is the effect of `higher-derivative terms'?

Trying to understand the limits

of the `AdS/CFT correspondence'

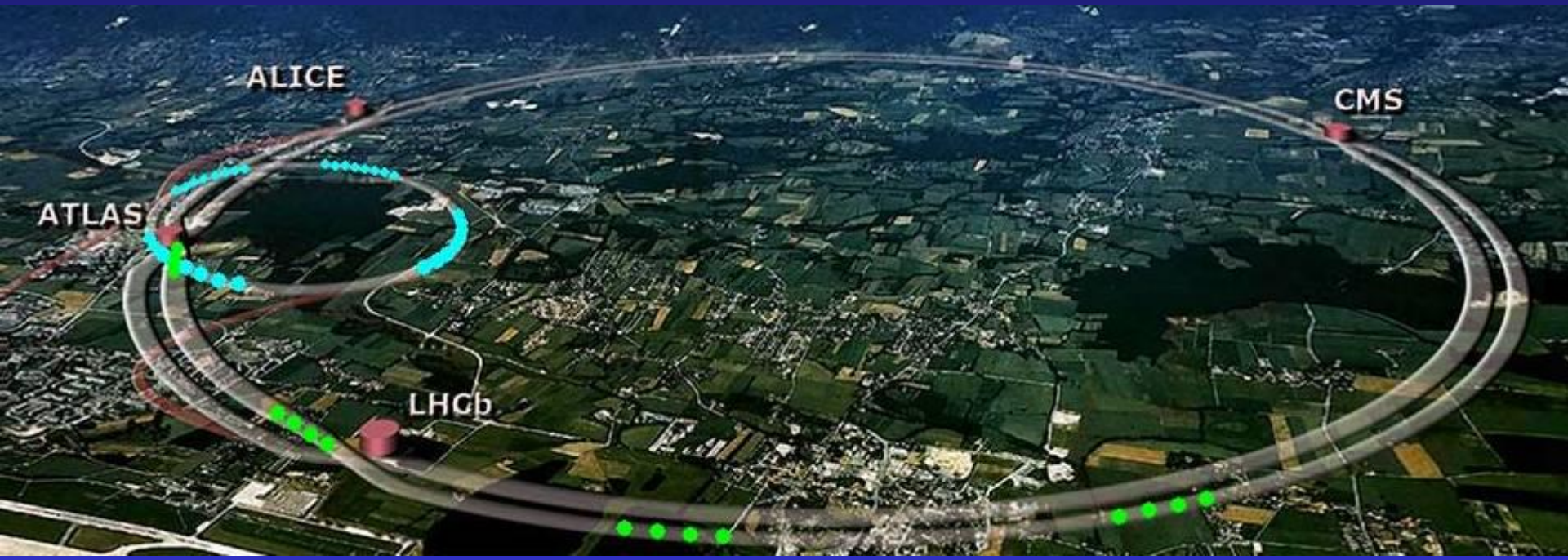
- What happens if you go beyond spin-2?
- Replace AdS by flat space
- What is the effect of `higher-derivative terms'?

(For simplicity we often work in three spacetime dimensions!)

there are experiments !

but no

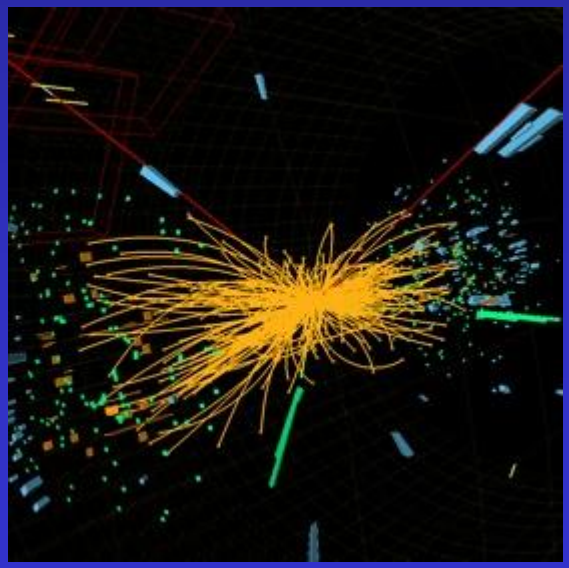
both at small distances



LHC at CERN (Switzerland)

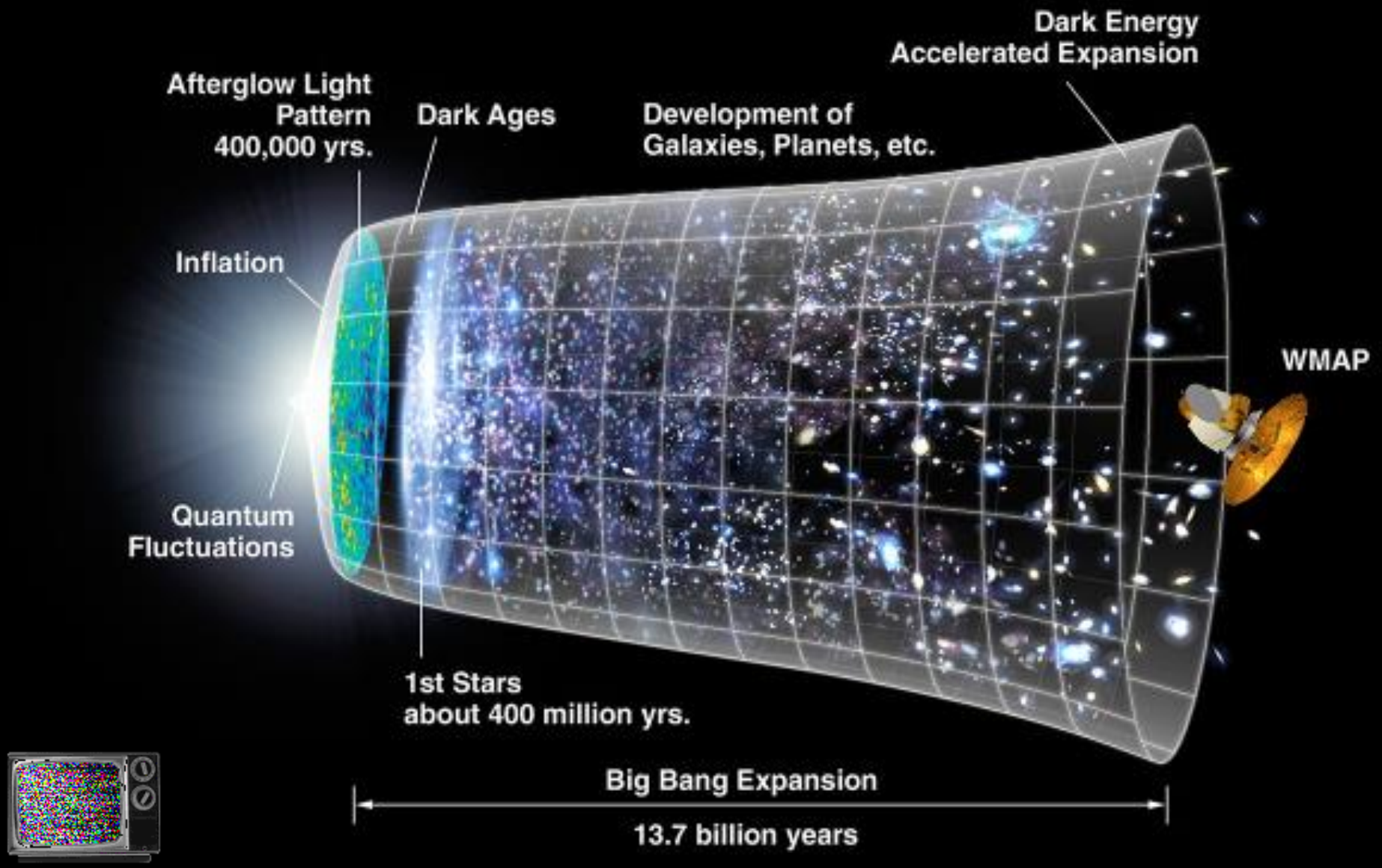
are we going to find new

"beyond the Standard Model'' physics ?

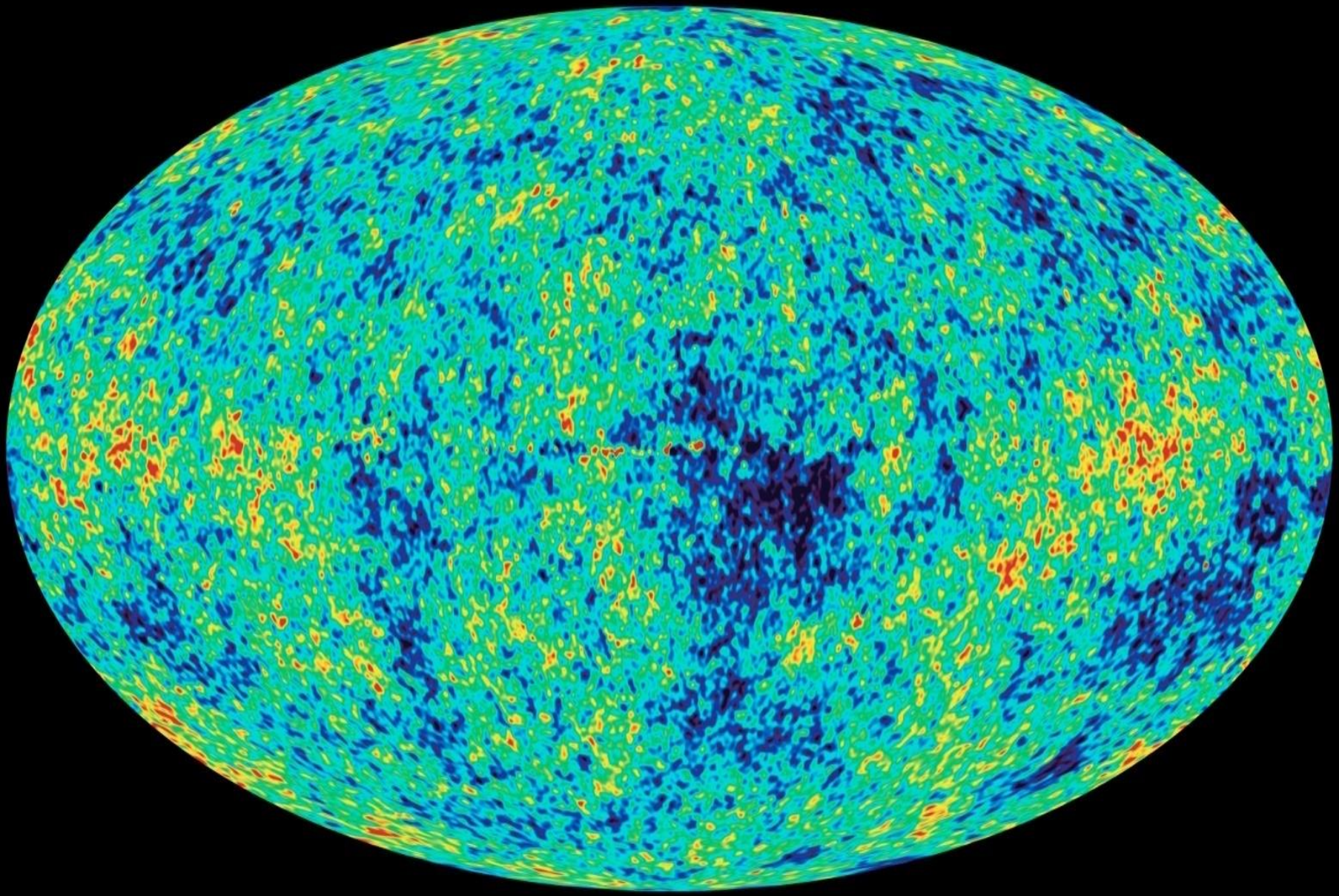


as well as at large distances !

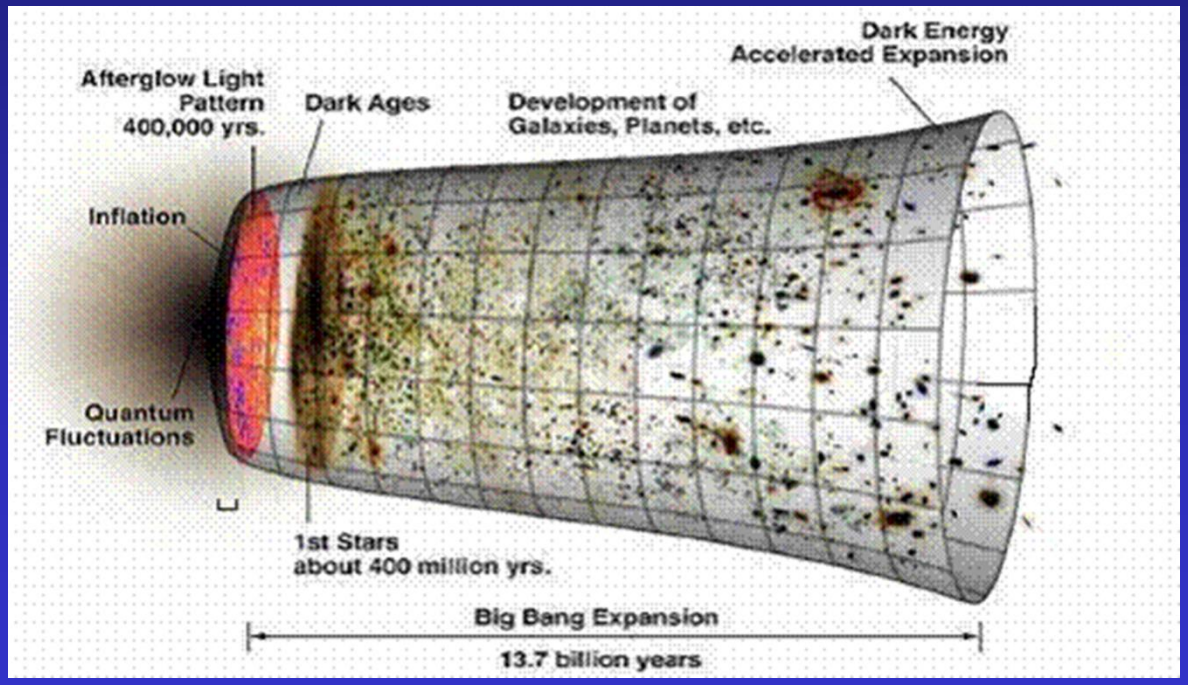
A brief history of the Universe



The cosmic microwave background



is the inflation scenario correct?



we live in a exciting time !

but . . . . .

gravity and quantum mechanics

have not married yet !


Thanks for your attention !