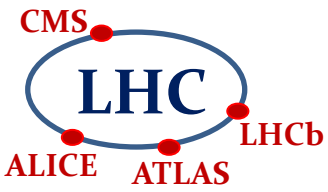
Is physics without experiment possible?

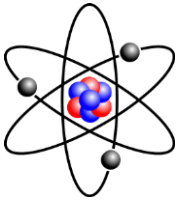
Stanisław Mrówczyński

National Centre for Nuclear Research, Warsaw, Poland

Scales of physical objects

physics of elementary particles



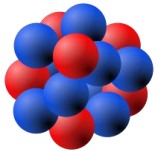


astrophysics & cosmology

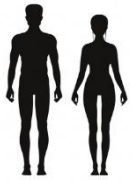
10^{-35} // 10^{-20} 10^{-15} 10^{-10} 1 10^{5} 10^{10} 10^{15} 10^{20} 10^{27} m

$$l_P \equiv \sqrt{\frac{\hbar G}{c^3}}$$

quantum gravity

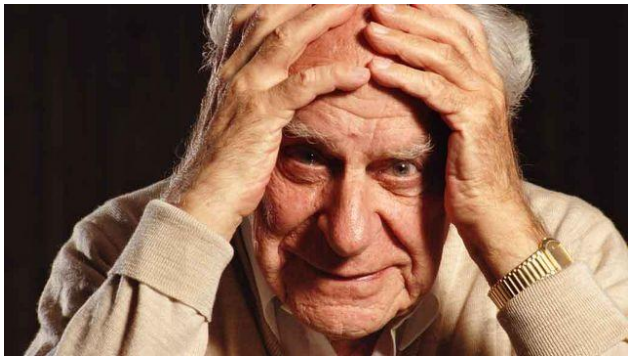


nuclear physics



observable Universe

Falsifiability – a pillar of physics

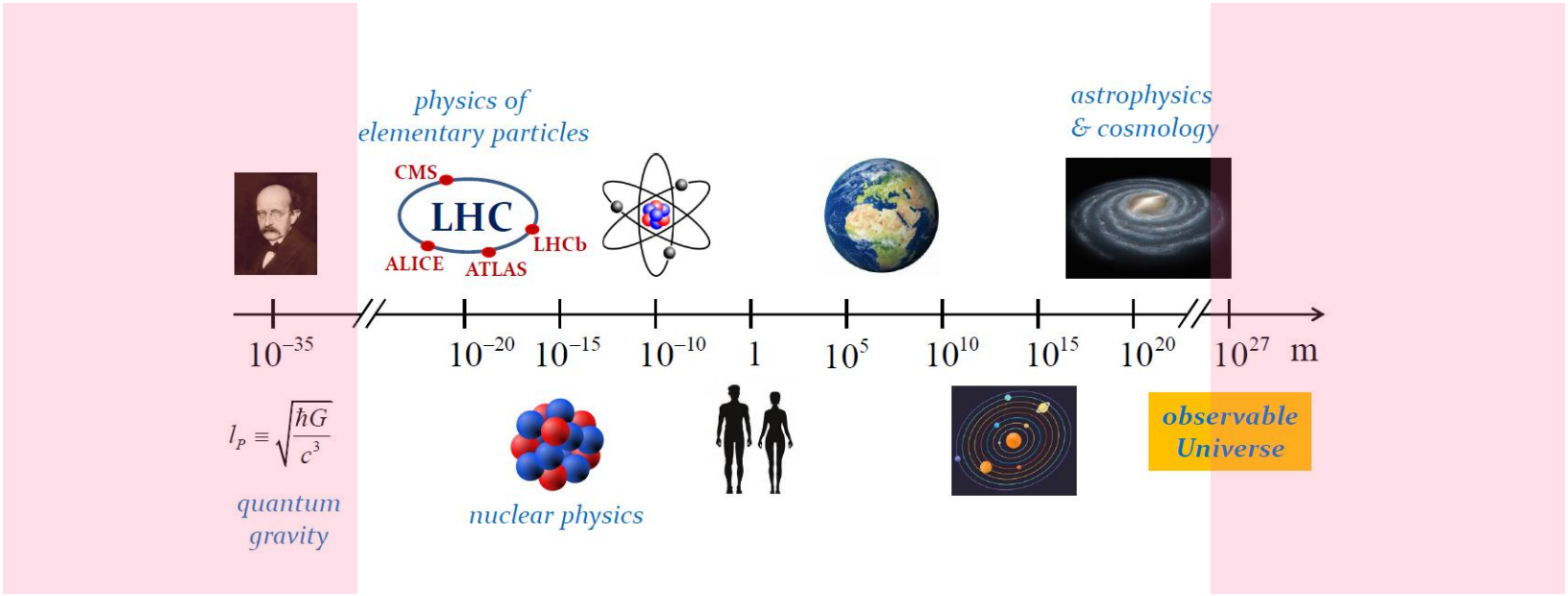


Karl Popper 1902-1994

A theory is scientific only if it is possible to establish that it is false!

Scientific theories are never finally confirmed,
but incrementally corroborated through
the absence of disconfirming evidence
in a number of well-designed experiments.

Technological limits of empiricism



Experimentally not accessible

Quantum gravity

$$l_P \equiv \sqrt{\frac{\hbar G}{c^3}} = 10^{-35}\ \text{m}$$

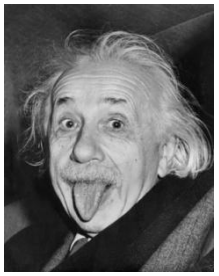
string theory?

loop gravity?

supergravity ?

$$m_P \equiv \sqrt{\frac{\hbar c}{G}} = 10^{19}\ \text{GeV}/c^2$$

classical limit



classical gravity

$$R^{\mu\nu} - \frac{1}{2}Rg^{\mu\nu} + \Lambda g^{\mu\nu} = \frac{8\pi G}{c^4}T^{\mu\nu}$$

General Theories of Everything

GTE

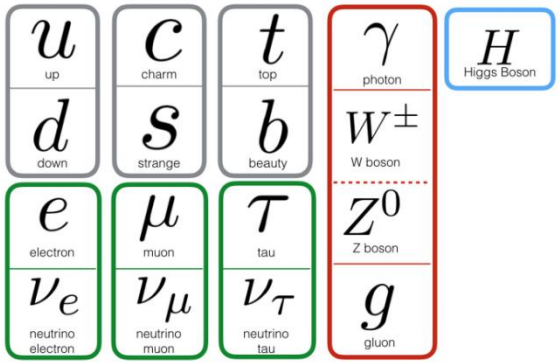
GTE

GTE

GTE

Low-energy limit

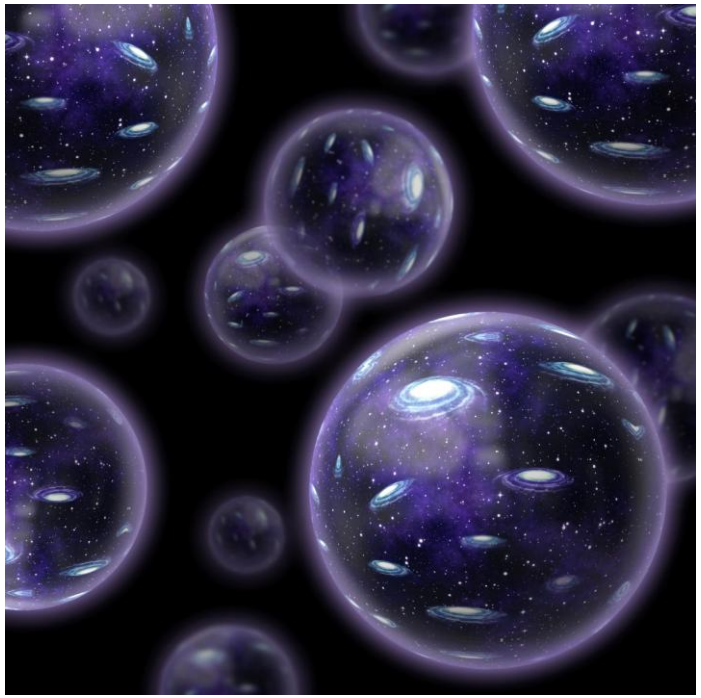
Standard Model



No physics beyond SM observed @ LHC

Principal limits of empiricism - Multiverse

From inflationary cosmological model to multiverse



Andrei Linde

Causally disconnected Universes

Is it still physics?

Fundamental limits of empiricism

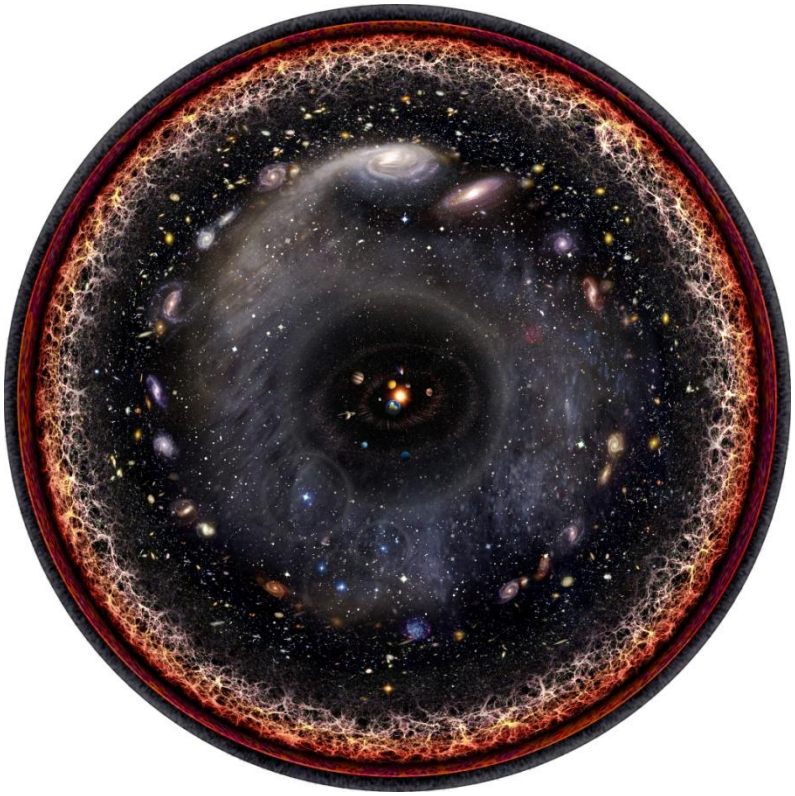
Cosmology

Cosmological principle

The observable part of the Universe is typical, representative of the whole.

Cosmological hypothesis

The laws of physics are the same, in any place and any time.



Log-scale image by Pablo Carlos Budassi

Deeper questions

From how? to why?

Example of the Coulomb law

The electrostatic force between two point charges is inversely proportional to the square of the distance between the charges.

Charles-Augustin de Coulomb (1736 – 1806)

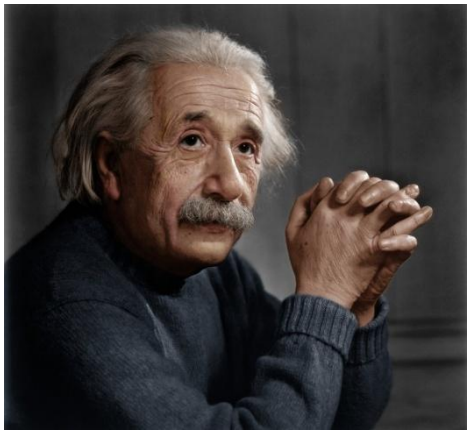
Why inverse squares?
Because photons are massless

Why photons are masslesss?
Because electrodynamics is gauge symmetric.

Why electrodynamics is gauge symmetric?
Because charges are conserved.

⋮

The ultimate question



Had God any choice in the creation of the World?

Interesting question but experimentally inaccessible

If not experiment then what?

Cartesian rationalism

René Descartes (1596-1650)

- *Logical consistency*
- *Agreement with experiments in limits*
- *No alternatives*
- *Minimum of assumptions and parameters*

Example of quantum gravity

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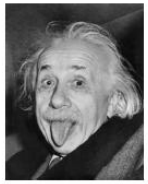

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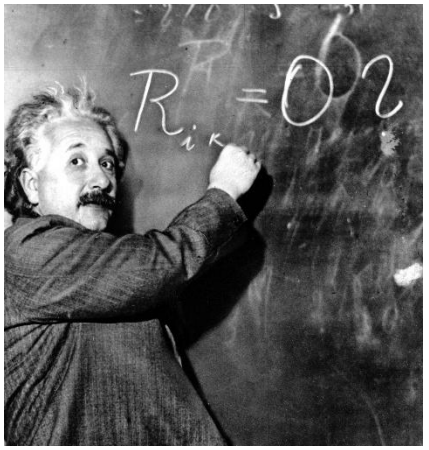
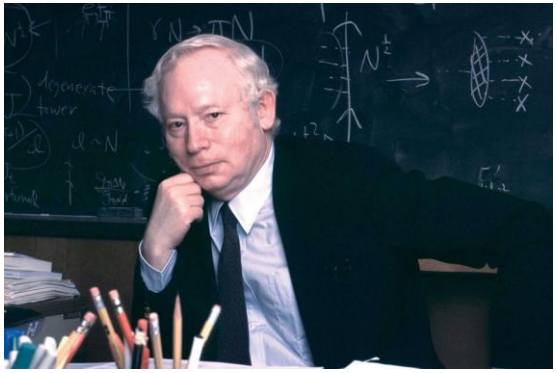
How it was with General Relativity

No experimental motivation to revise the newtonian gravity.

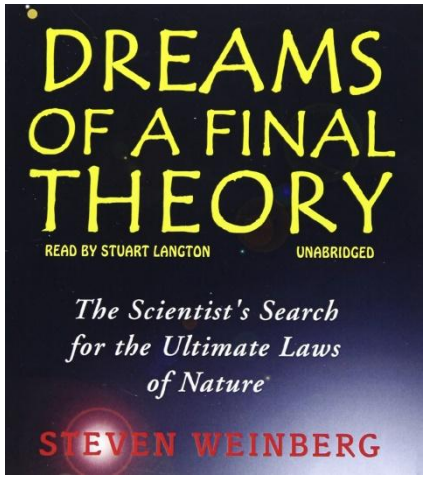
Why GR was commonly accepted soon after the discovery?



- *Precession of Mercury's Perihelion*
- *Gravitational deflection of light*



Steven Wienberg (1933-2021)



Chapter 5
Tales of Theory and Experiment

Physics, philosophy & scientific method

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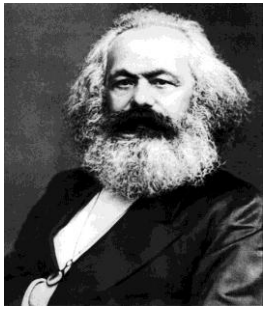
Epilogue



A spectre is haunting Physics

– the spectre of post-empiricism.

All the powers of old physics have entered into a holy alliance
to exorcise this spectre.

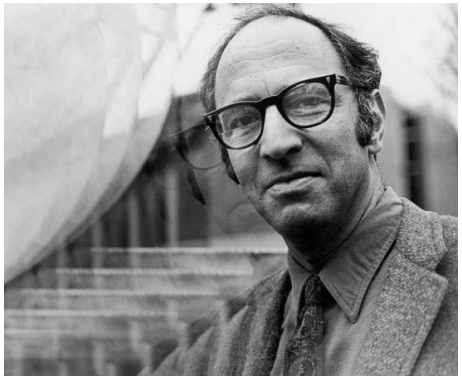
Breakthrough Prize in Fundamental Physics ($3 milion) was awarded in 2019 to S. Ferrara, D. Freedman & P. van Nieuwenhuizen for supergravity.

APS Sakurai Prize was awarded in 2019 to Lisa Randall & Raman Sundrum for warped extra dimensions, and in 2020 to Pierre Sikivie for a method to detect axions.

Outlook

Paradigm shift?

„The answers you get depend upon the questions you ask."



Thomas Kuhn (1922-1996)