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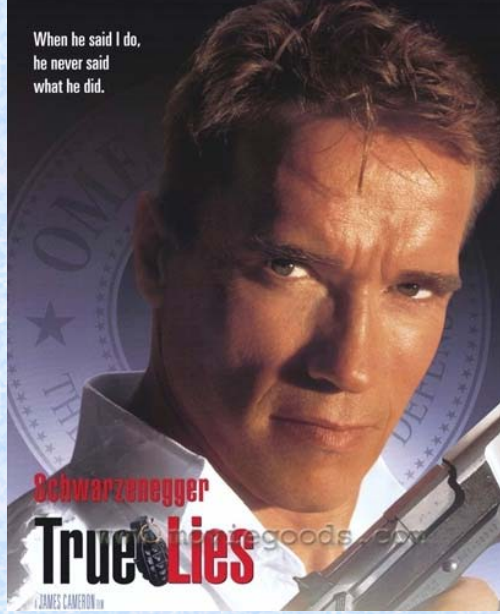
Fundamental Lies?

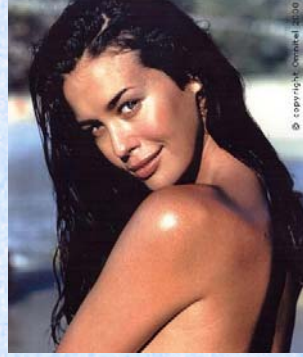


The Manifesto we are teaching :

- Physics deals with space, time and energy
- Space-time is R^4
- Physical laws are the same:
  - Every-where
  - Every-when
  - On every scale
- Lorentz invariance holds
- Pauli principle holds
- CPT holds...

As far as we know, all this looks true, but are these fundamental laws or fundamental lies?

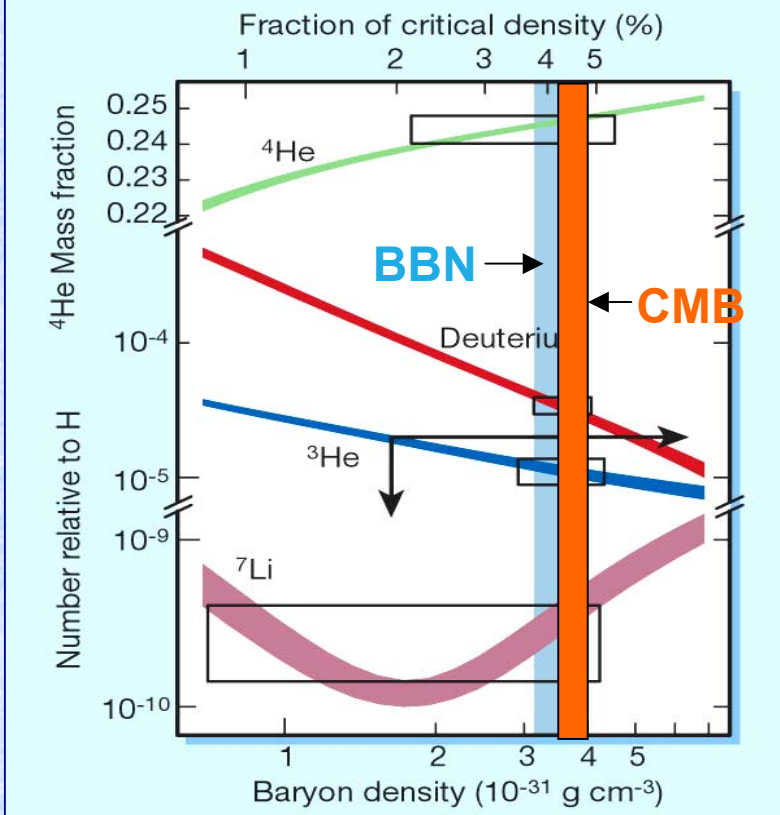
Physical laws look the same everywhere at any time

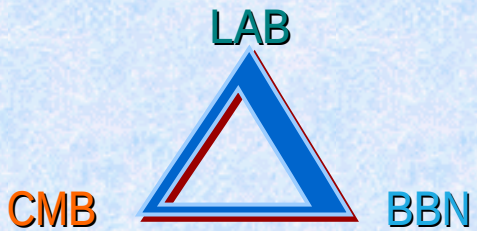


Source	Where	When (from BB)	What
Oklo	Earth	12 Gyr	The first nuclear accident (constancy of nuclear physics)
Meteorites	Solar system	10 Gyr	Concordance of radioactive datings
^{12}C formation	Stars	5 Gyr	Her existence (nuclear levels unchanged)
Old stars	Galaxy	3 Gyr	Concordance of datings
(QSO) ?	Universe	1 Gyr	Constancy of atomic physics?
CMB	Universe	$3\ 10^5$ yr	Concordance of n_p/n_γ
BBN	Universe	3 min.	

The concordance between BBN and CMB

- CMB shows the universe at $t \approx 4\ 10^5$ yrs; $z \approx 10^3$ $T \approx 0.3$ eV.
- During BBN, Deuterium is produced at $t \approx 100$ s $z \approx 10^8$ $T \approx 0.1$ MeV
- Data on n_p/n_γ from CMB are in agreement with those obtained from primordial abundances (mainly D) assuming Laboratory nuclear physics inputs.



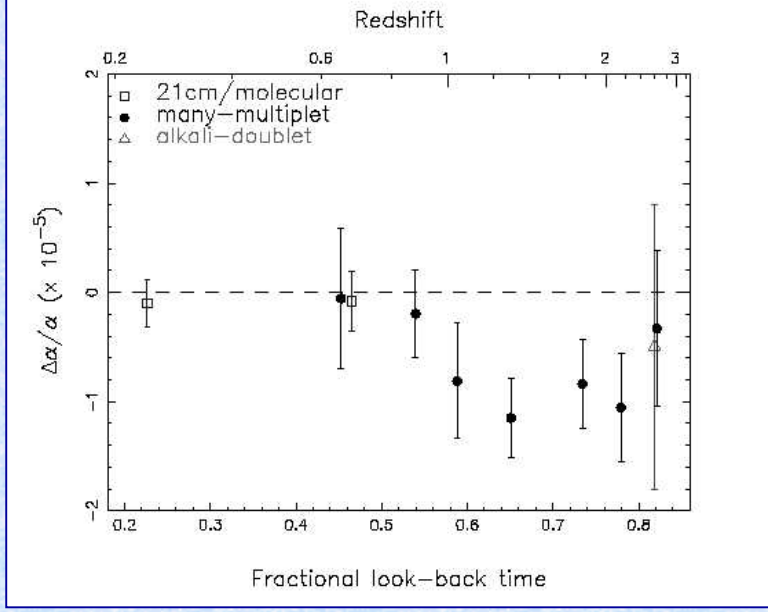


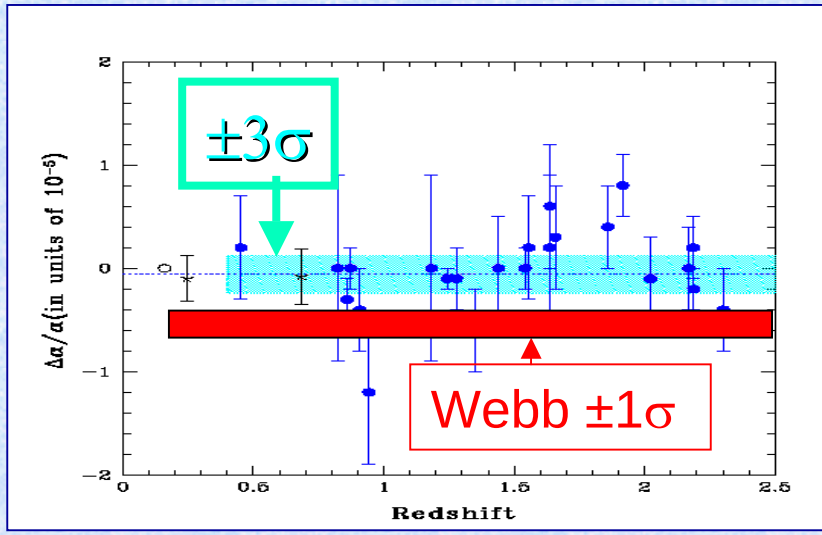
Astonishing !

However?

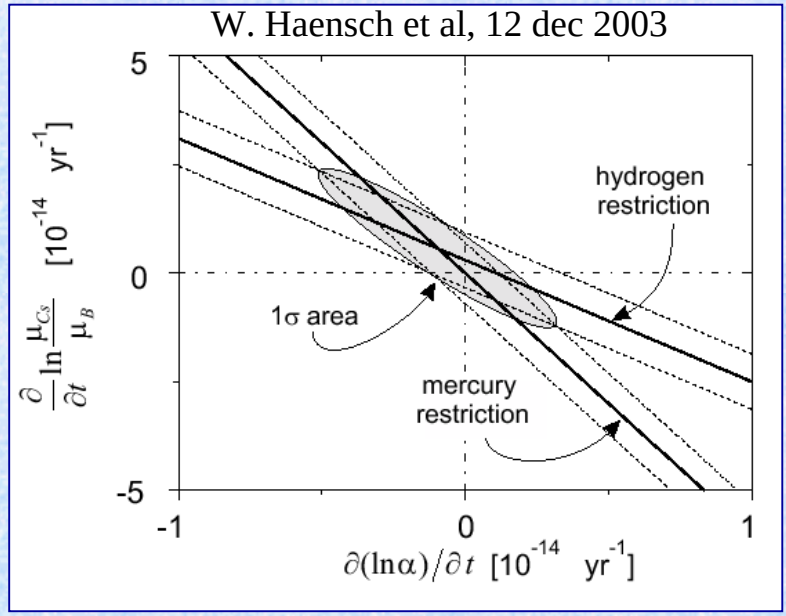
- Controversial and debated implications from QSO spectra.
- Re lifetime measured in the lab seems different from that inferred with geochemical methods from meteorites.

  $2\beta(2\nu)$: inconsistency between lab. and geochemical data.
- There is some smoke, but no smoking gun.





Big lever-arms or high precision expts?



- Can explore high energy physics with huge accelerators or high precision expteriments, e.g. **(g-2)**$_\mu$

- Similarly, tiny changes of α in the present universe can be detected by comparing 2 "clocks", their frequencies depending differently on α :

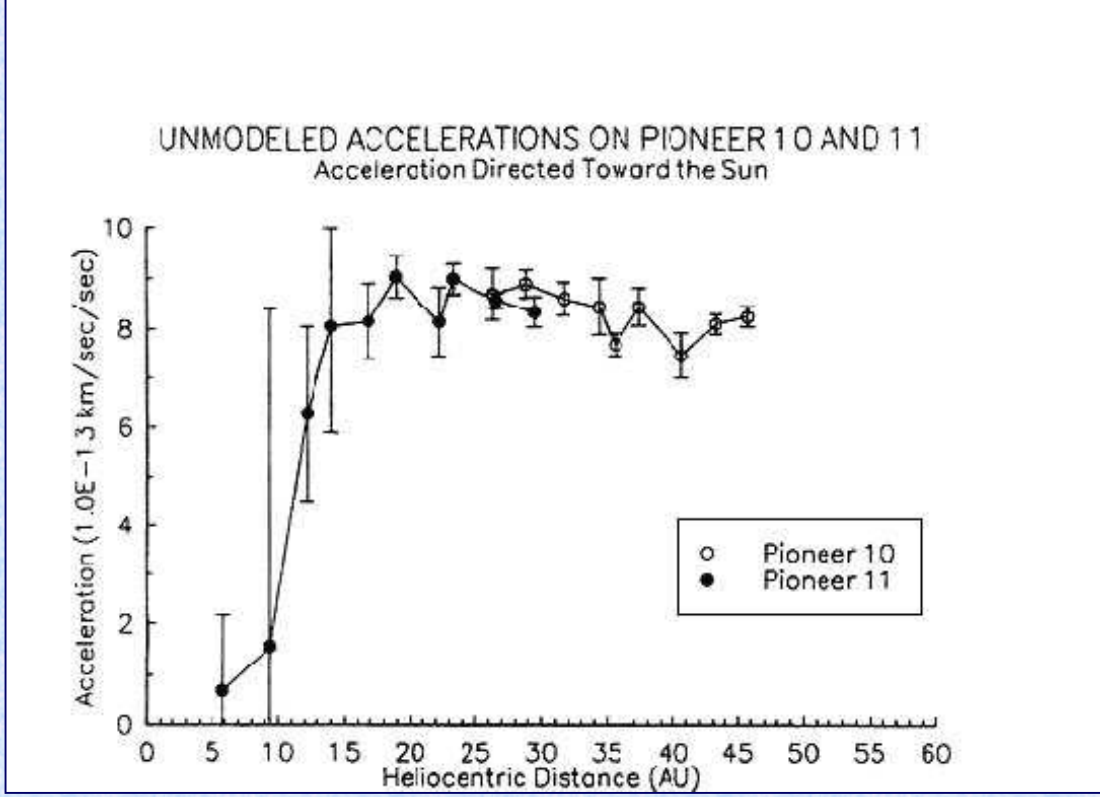
$$\dot{\alpha}/\alpha = (-0.9 \pm 4.2)10^{-15}\, yr^{-1}$$

- Ultimate limit for frequency measurement is observation time. Cold atoms in lab. fall due to gravity. Atoms in free fall don't fall, so go to space…

Is physics the same at any scale?

- A warning: the Pioneer anomaly on solar system scale.

- For both Pioneer 10 and 11, at the border of solar system, there is an unexplained residual acceleration pointing towards theSun



Residual acceleration is 10^{-7}cm s^{-2}, same order as that advocated by MOND, the theory originally invented to avoid dark matter by modifying Newton law for bodies at small acceleration.

?

An emerging sub millimeter scale?

- Attempt for explaining why gravity looks so weak has brought us large extra-dimensions, degrading G_N to an effective constant , $G_N=G_{4+D}(L_{extra})^{-D}$, and introducing an experimentally appealing scale:

$$L_{extra}=(1\mu m\text{-}1mm)$$

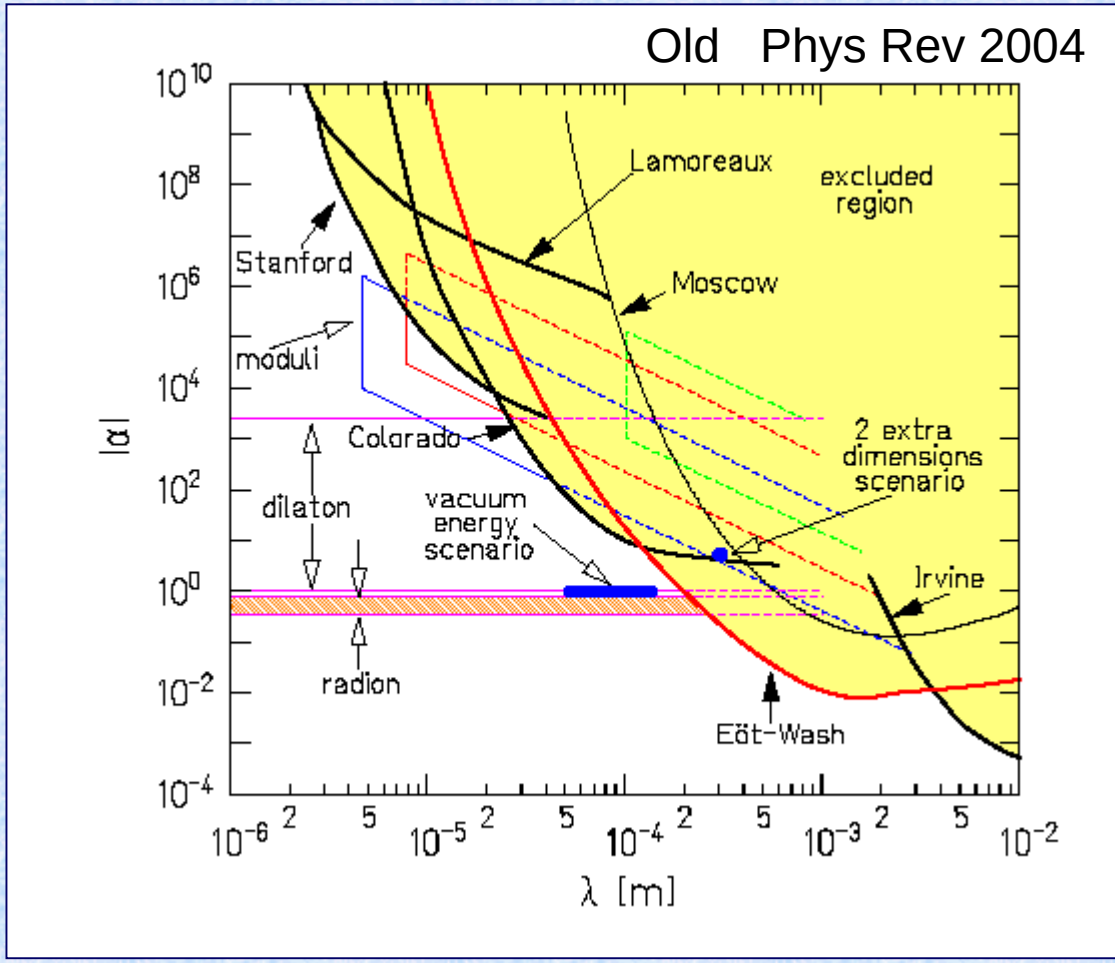
- Similar length scale arises from vacuum energy density.

- L_{extra} is perhaps a trade off between $L_{Universe}=10^{28}cm$ and $L_{Planck=}=10^{-33}cm$:

$$\sqrt{L_{Universe}L_{Planck}} \approx 30\mu m \approx L_{extra}$$

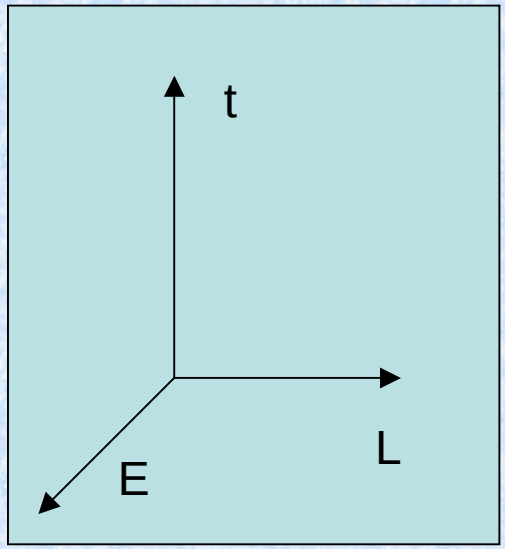
Eot-something

- Refined Sub-millimeter tests of the Gravitational Inverse-square Law recently performed.
- The interesting region is being explored
- Good luck !



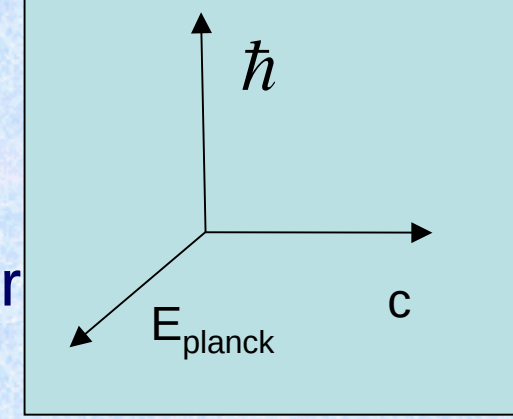
Physics deals with space, time and energy

- We know that the result of any physical measurement can be expressed in terms of just **three** quantities.
- This is the present level of understanding the relationships between physical quantities
- It has not been always so (e.g. : energy and temperature)



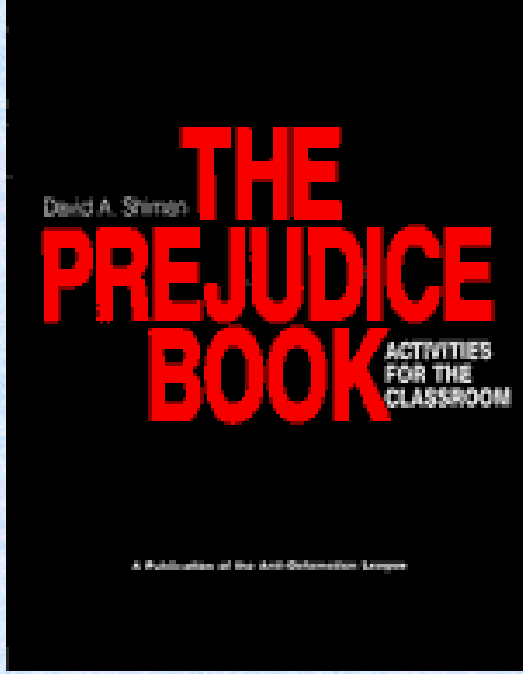
- Why not more? Why not less?

Natural units



- To translate physical measurements into numbers we need to agree on the values of measurements for selected sample, the units of measurements.
- As nature provides us with three such samples we are free to use them, and label these as the present "fundamental constants"
- ("fundamental units" is a better expression)
- Remarks:
  - It makes no sense to ask if any of these varies.
  - It makes sense to ask if dimensionless quantities (e.g. $\alpha = e^2 / \hbar c$) vary.
  - In the course of history some "fundamental constants" have been degraded to conversion parameters (E=kT)
  - It makes sense to ask if we really need all of them…

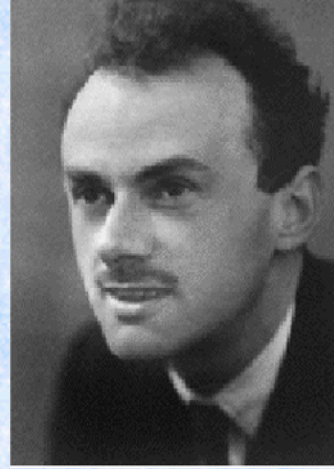
Progress in physics is often the overcome of prejudices:



- The destruction of Ether
- Energy quantization
- Parity violation
- CP
- Non vanishing neutrino masses
- Vacuum energy
- ….

- Theoretical guidance, often invoked by experimentalists, is best used after experimental discovery…

Dirac's legacy



- In a letter to Nature in 1937 Dirac noted the following coincidence:

$$N_1 = \frac{e^2}{G m_N m_e} \approx 2.3 * 10^{39} = \frac{\text{electric force between proton \& electron}}{\text{Gravitational force between proton \& electron}}$$

$$N_2 = \frac{t_o}{e^2 / m_e c^2} \approx 6 * 10^{39} = \frac{\text{age of universe}}{\text{atomic light - crossing time}}$$

"…This suggests that …large numbers are to be regarded not as constants, but as simple functions of our present epoch, expressed in atomic units. In this way we avoid the need of a theory to determine numbers of the order of 10^{39} ".

- We are essentially rephrasing his problems in a different language ("hierarchy problem" , Why $L_{universe}/L_{Planck} \approx 10^{61}$?), perhaps without much deeper understanding.

- I believe that his conclusion is still actual:

…the constancy of the fundamental physical constants should be checked in an experiment.