Hacking the Universe

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26c3 “Here Be Dragons”, 2009

The Plan

1. Introduction
2. Cosmology
3. Particle Physics — LHC
4. String Theory
5. Open Source Physics?

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Researcher in String Theory (and quantum gravity, cosmology, particle physics, quantum information, protein folding)

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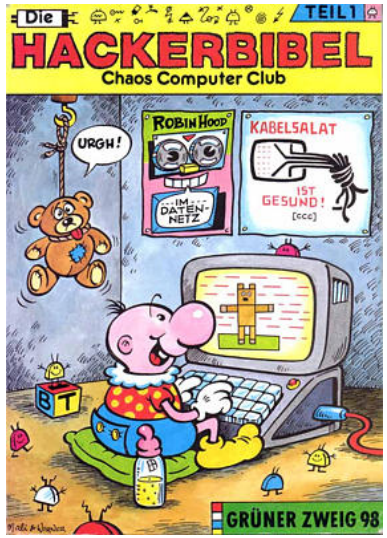
My first computer

My first computer that worked

My first modem

The problem:



Why am I here?

If you can't open it, you don't own it!

makezine.com

THE MAKER'S BILL OF RIGHTS

■ Meaningful and specific parts lists shall be included. ■ Cases shall be easy to open. ■ Batteries shall be replaceable. ■ Special tools are allowed only for darn good reasons. ■ Profiting by selling expensive special tools is wrong, and not making special tools available is even worse. ■ Torx is OK; tamperproof is rarely OK. ■ Components, not entire subassemblies, shall be replaceable. ■ Consumables, like fuses and filters, shall be easy to access. ■ Circuit boards shall be commented. ■ Power from USB is good; power from proprietary power adapters is bad. ■ Standard connectors shall have pinouts defined. ■ If it snaps shut, it shall snap open. ■ Screws better than glues. ■ Docs and drivers shall have permalinks and shall reside for all perpetuity at archive.org. ■ Ease of repair shall be a design ideal, not an afterthought. ■ Metric or standard, not both. ■ Schematics shall be included.

Make: technology on your time

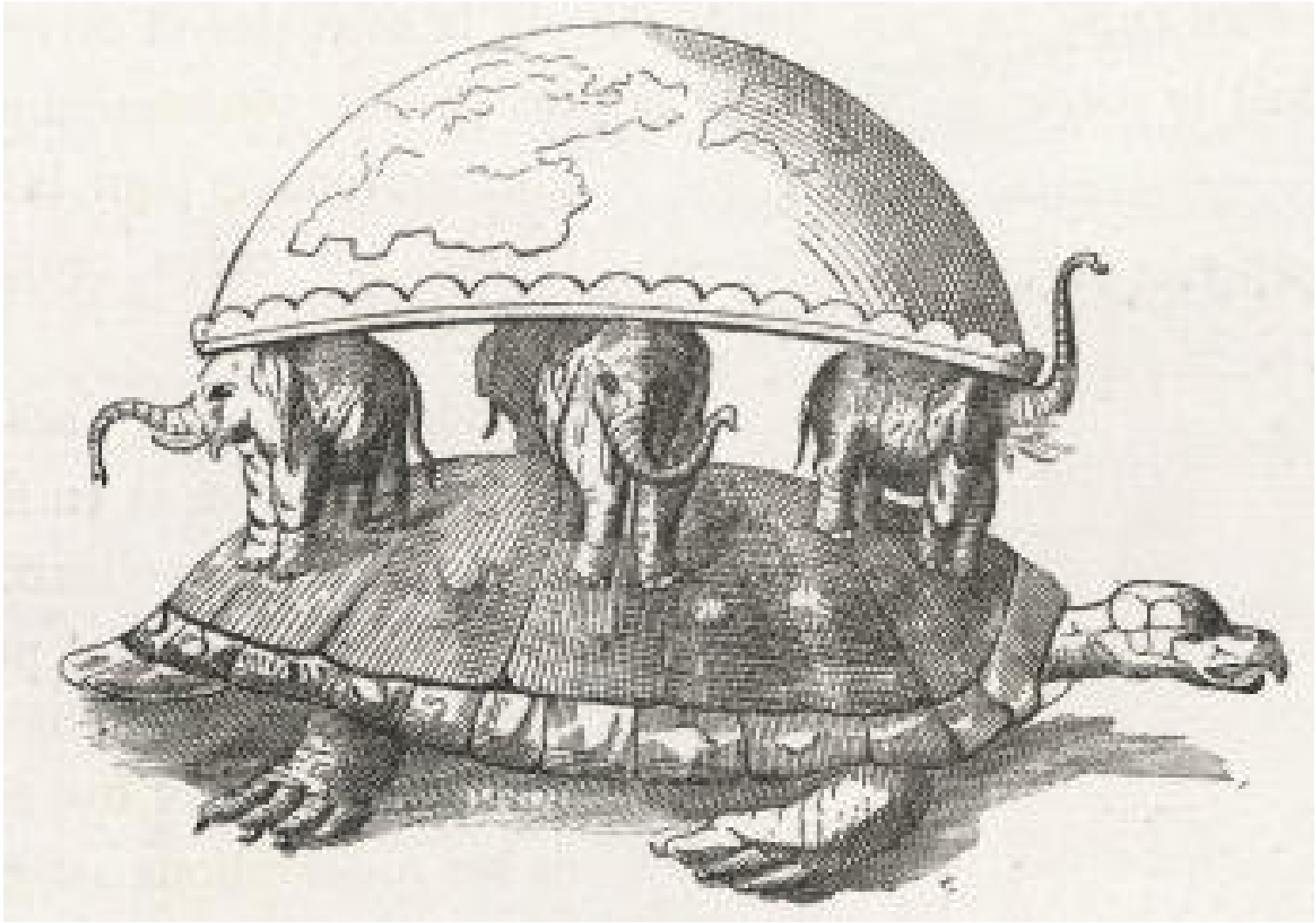
Drafted by Mister Jalopy, with assistance from Phillip Torrone and Simon Hill.

hacker: n.

1. A person who enjoys exploring the details of programmable systems and how to stretch their capabilities, as opposed to most users, who prefer to learn only the minimum necessary. RFC1392, the Internet Users' Glossary, usefully amplifies this as: A person who delights in having an intimate understanding of the internal workings of a system, computers and computer networks in particular.

(The jargon file)

Cosmology



Can we understand the universe as a whole?
Until 1960s, mainly guesswork.

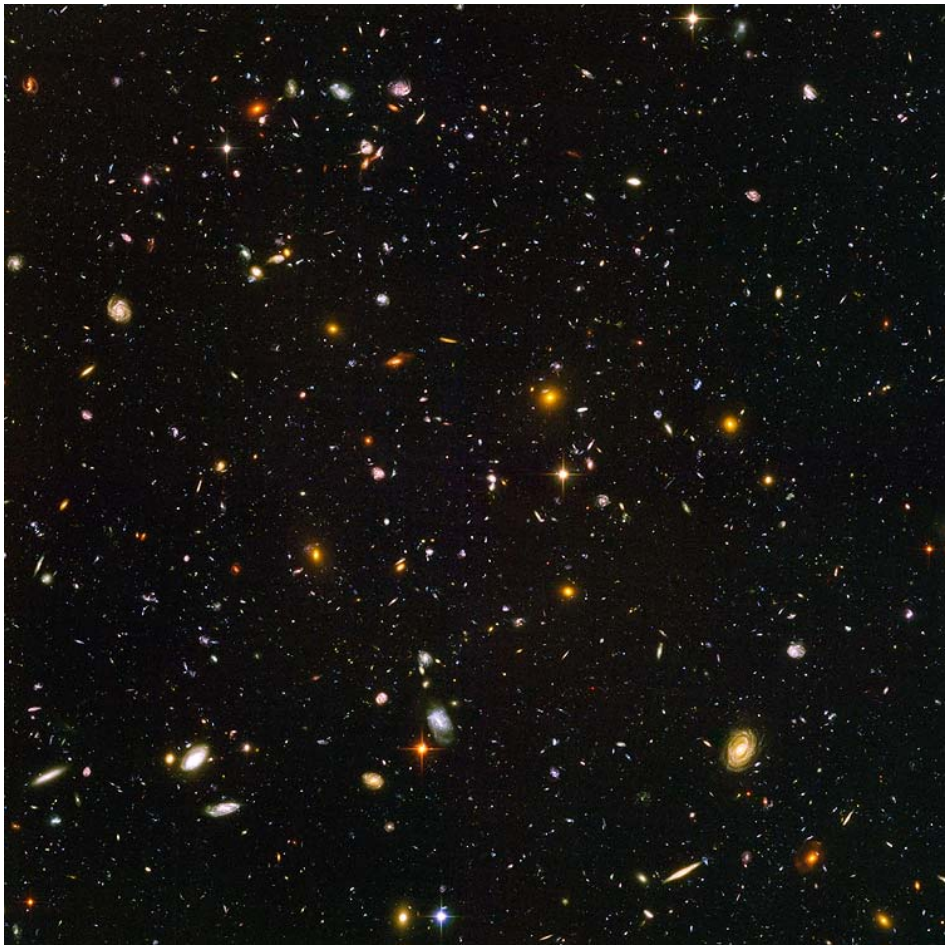
Space, the final frontier . . .

Hubble law:
Star's distance $\sim$ Star's velocity

Explanations:
(1) We are in the center
(2) The universe is expanding.

Has this been going on forever ("Steady State", matter is created as space expands) or was there a "Big Bang"?

This is what the empty sky looks like:
Hubble Deep Field

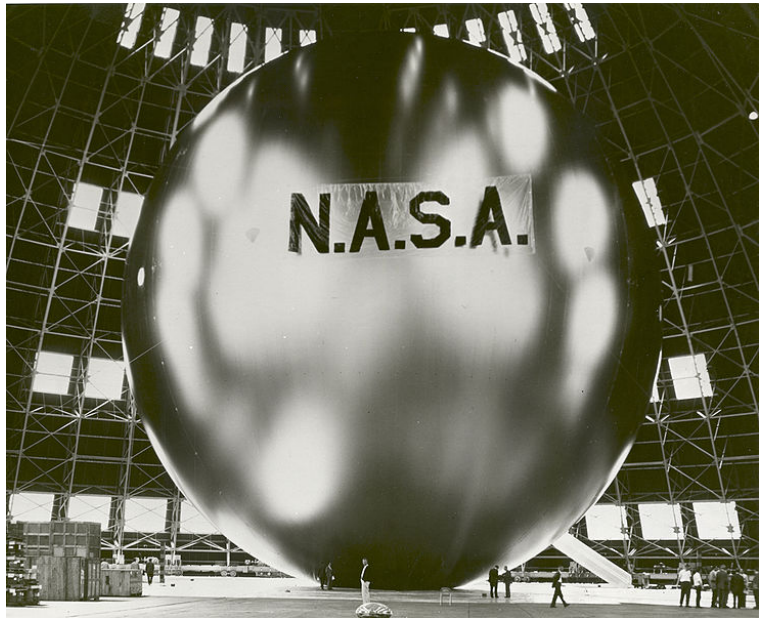


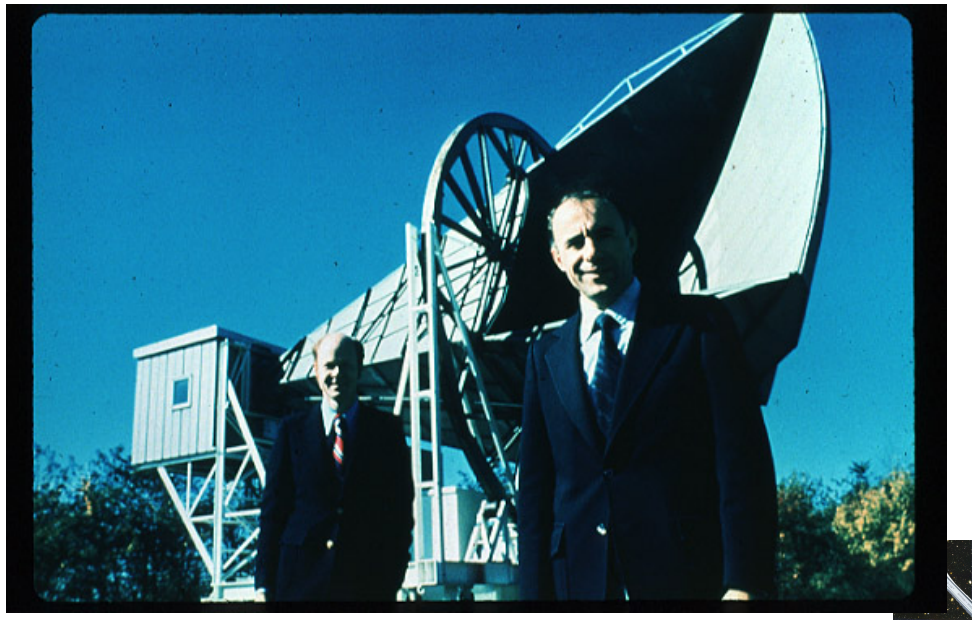
Noise in the antenna

In 1965, Bell Labs' Arno Penzias and Robert Wilson worked on a microwave antenna that was to receive radio signals from a passive telecommunications satellite (essentially a coated 30m balloon).

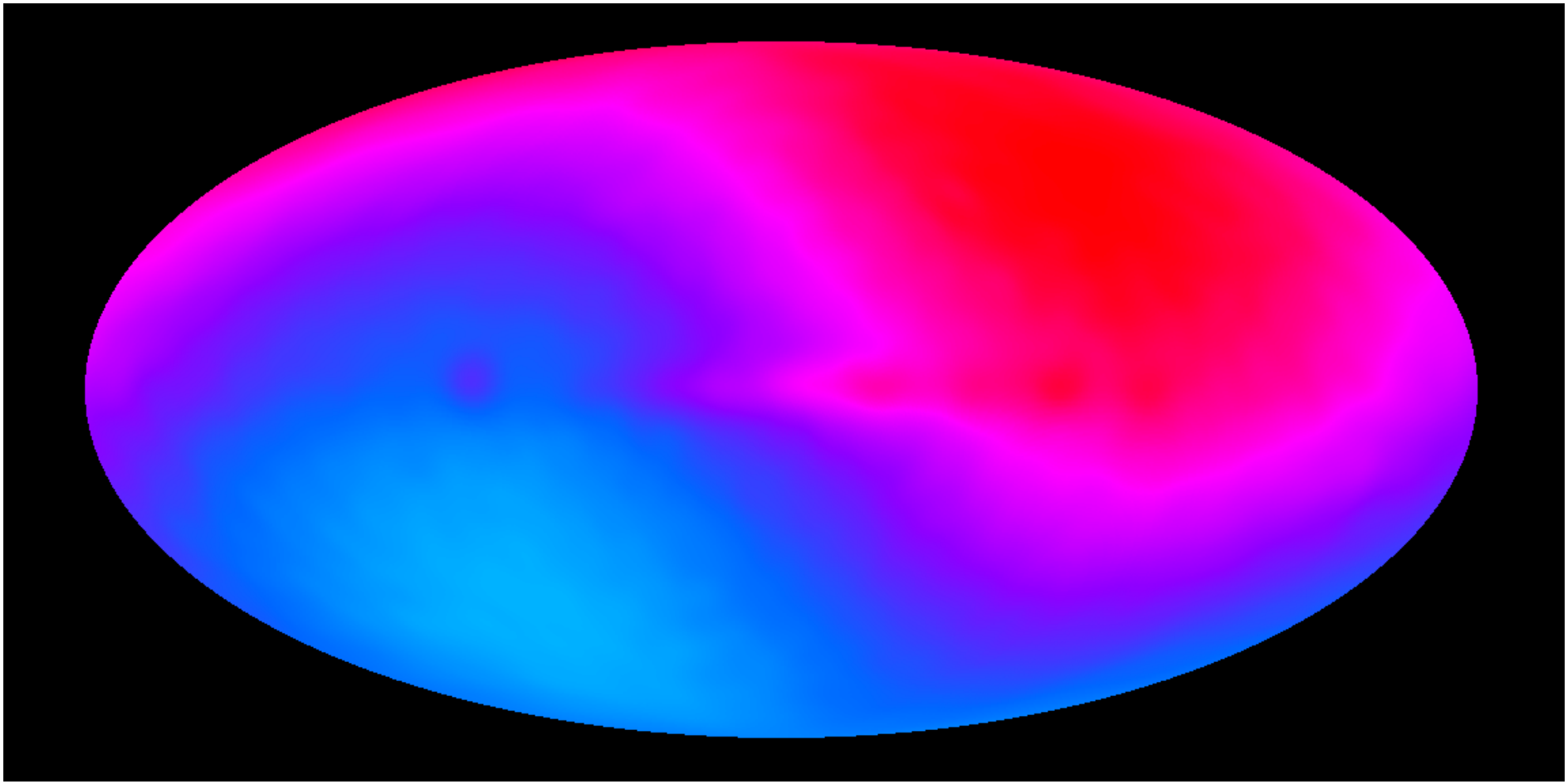
They could not get rid of 3.3K of excess noise.

After speaking to physicists at Princeton, they realised they had measured the afterglow of the Big Bang, the Cosmic Microwave Background that had been predicted ealier by several cosmologists.

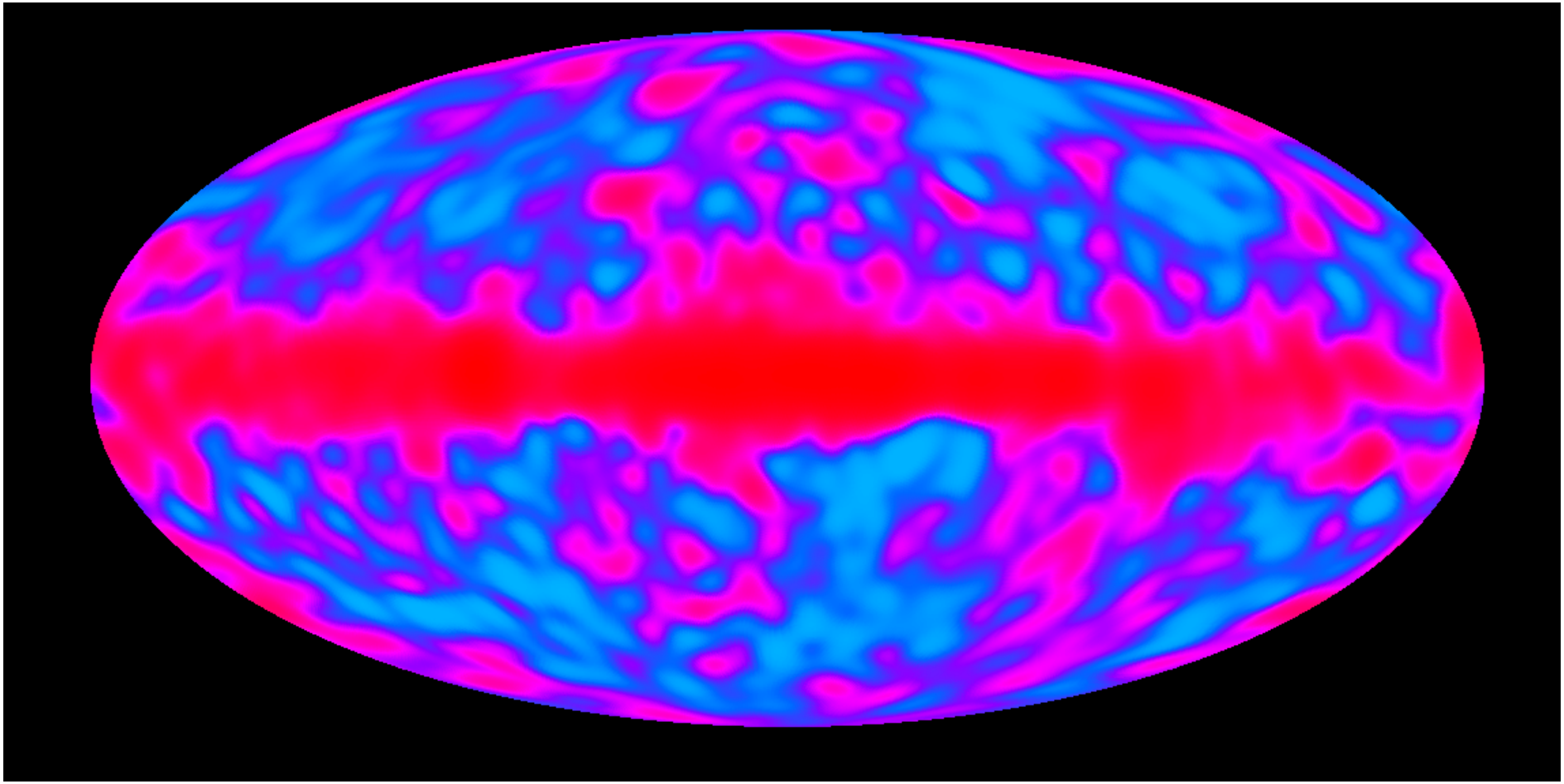




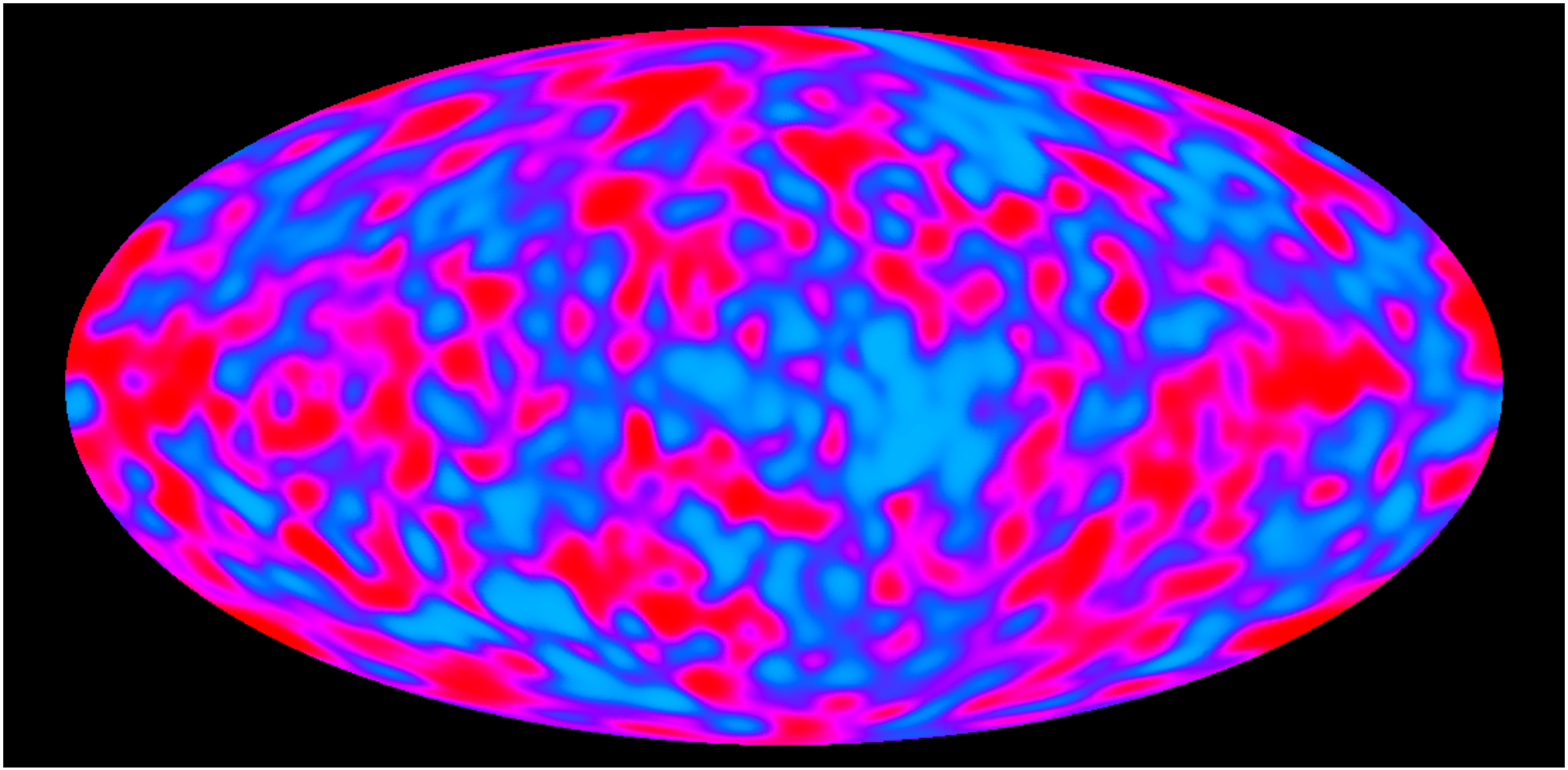
The most perfect black body spectrum 2.7K



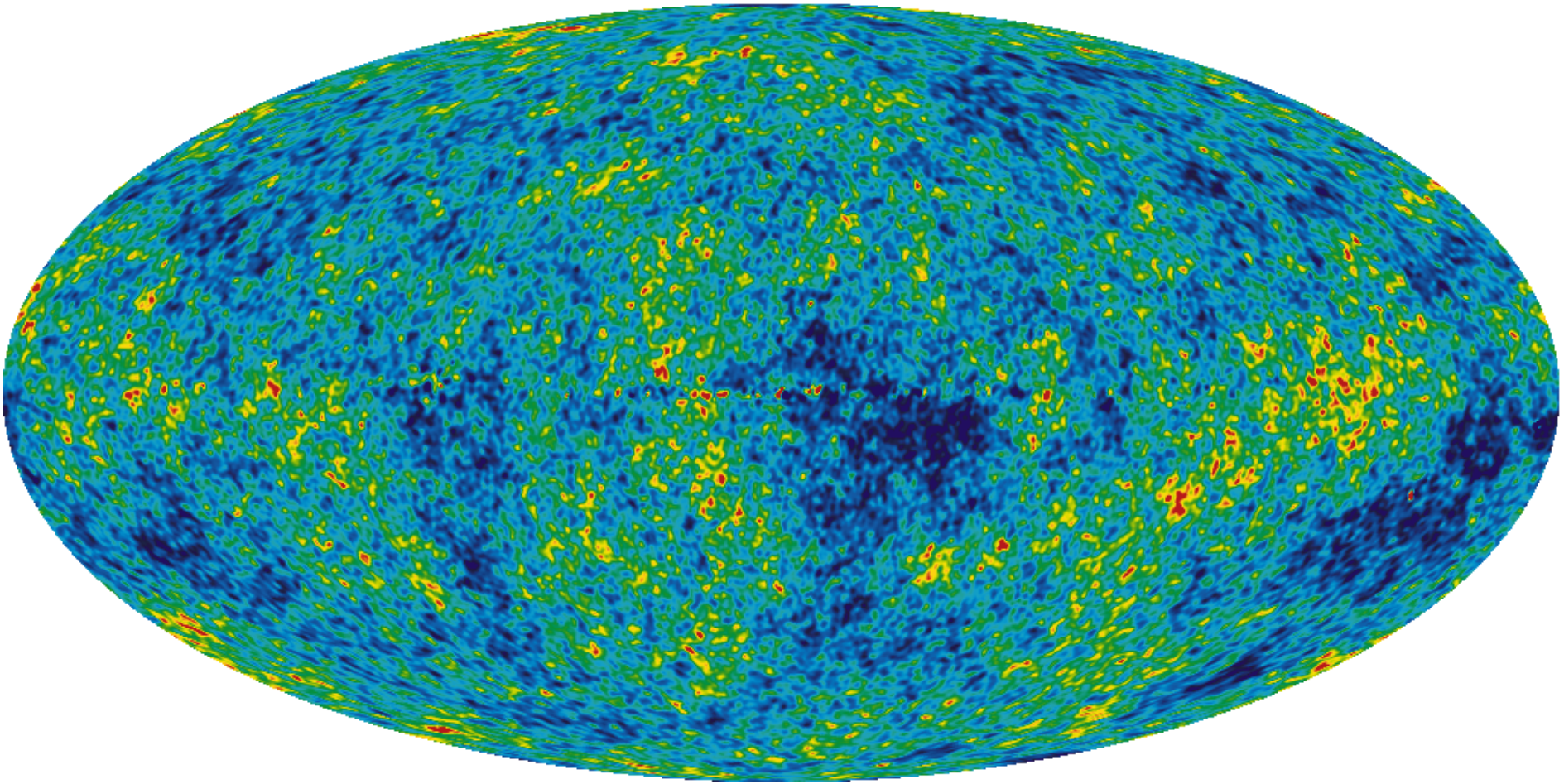
Remove Doppler shift [999/1000 of variation]



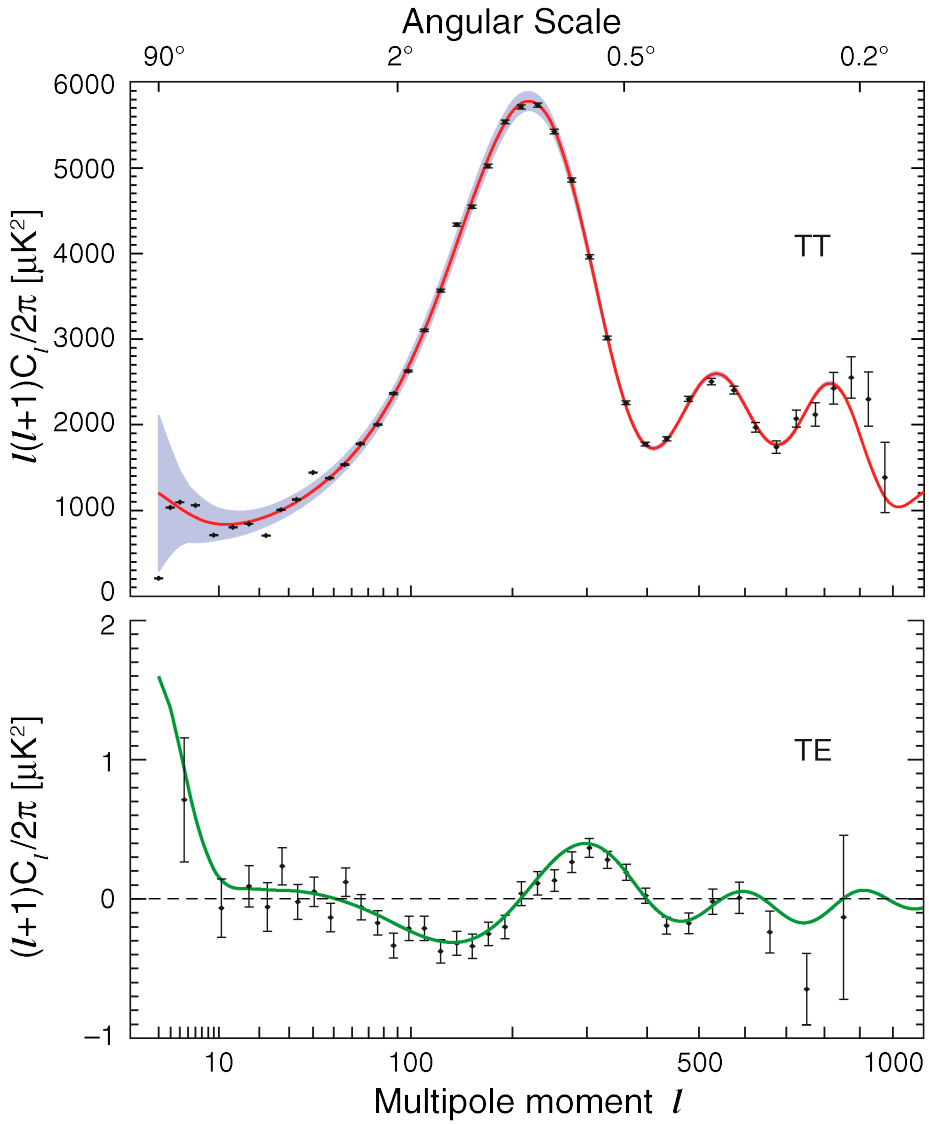
Remove foreground $\longrightarrow$ Nobel prize 2008



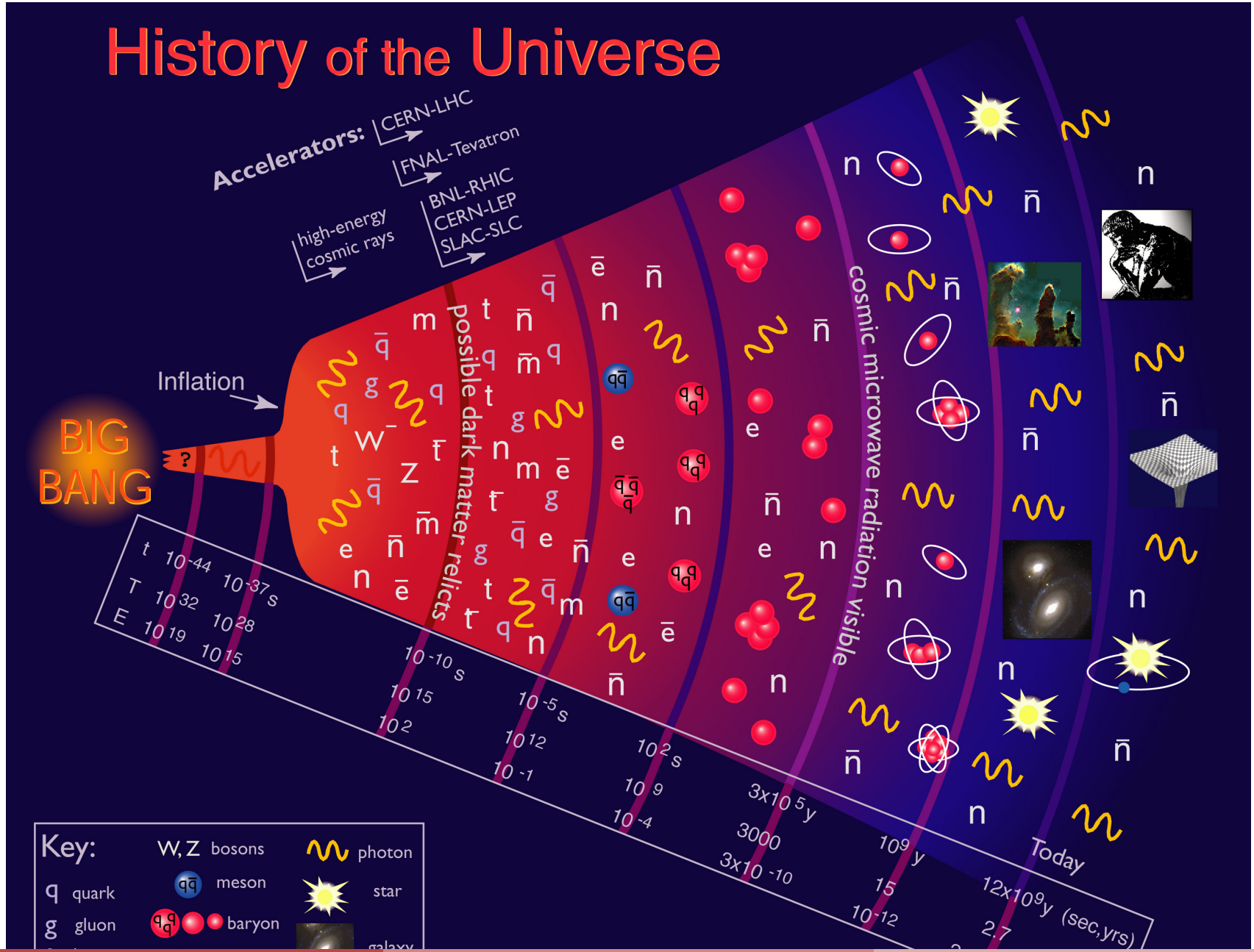
With WMAP satellite [Planck to follow]



But the actual data is in the distribution over angular scales



This data is turned into



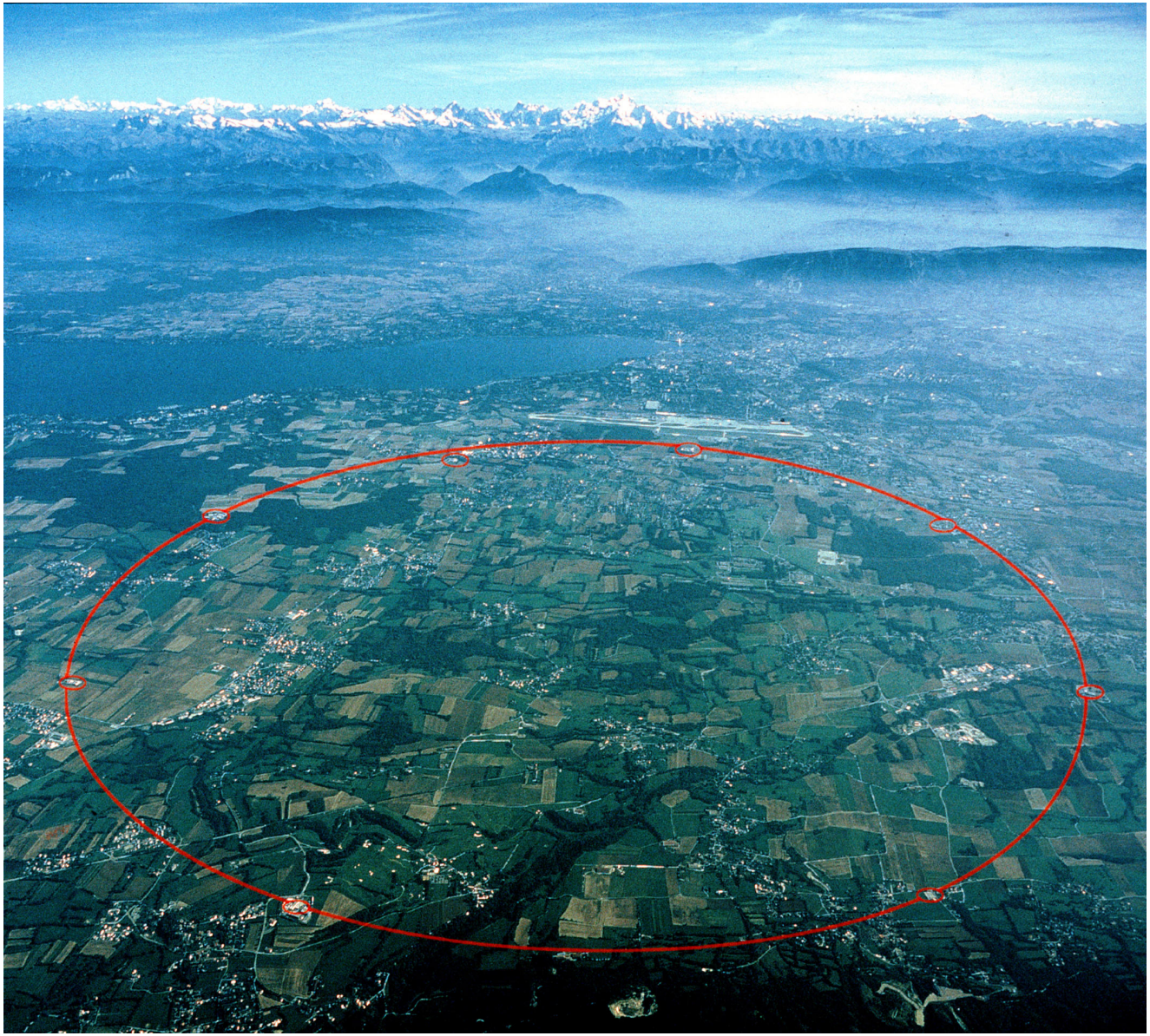
To investigate small things . . .

. . . you use a microscope.

To investigate smaller things . . .

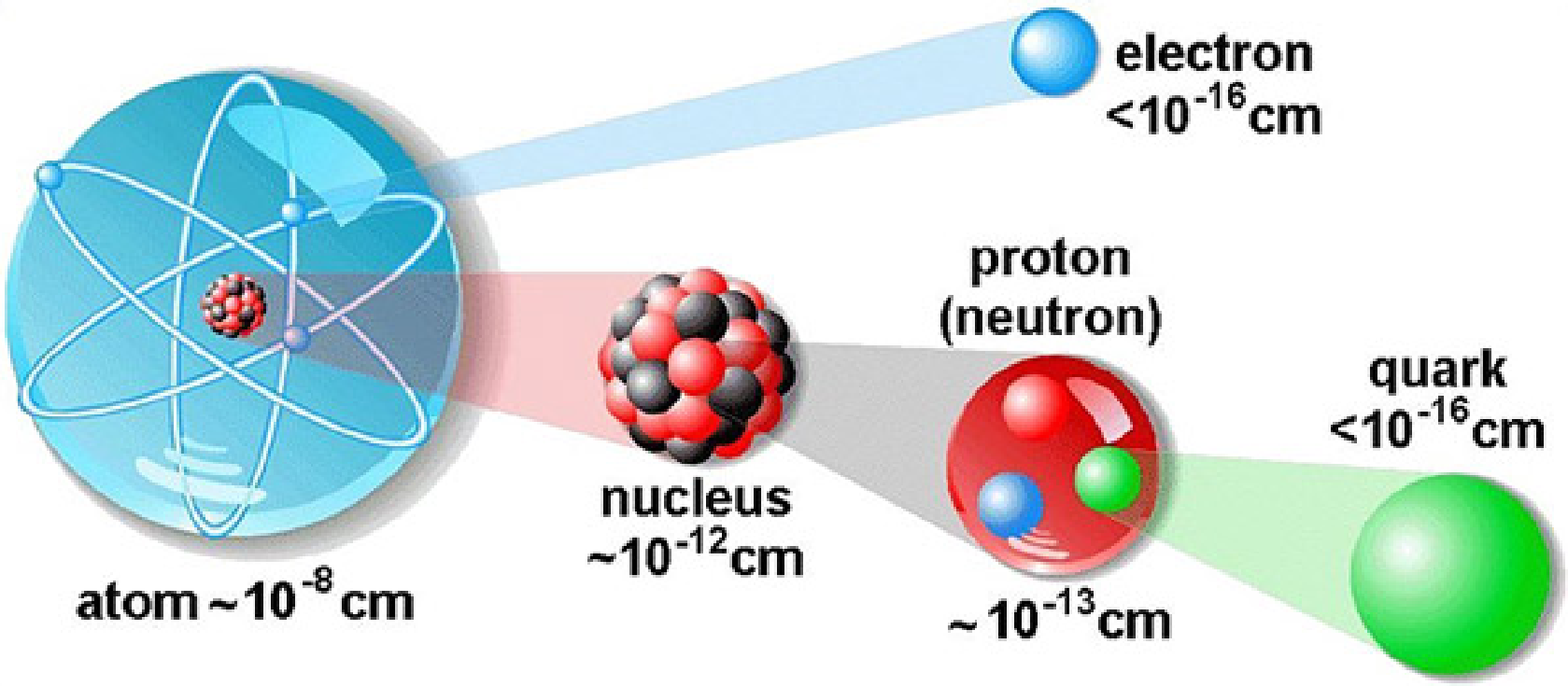
. . . you use a bigger microscope.

For really small things ...

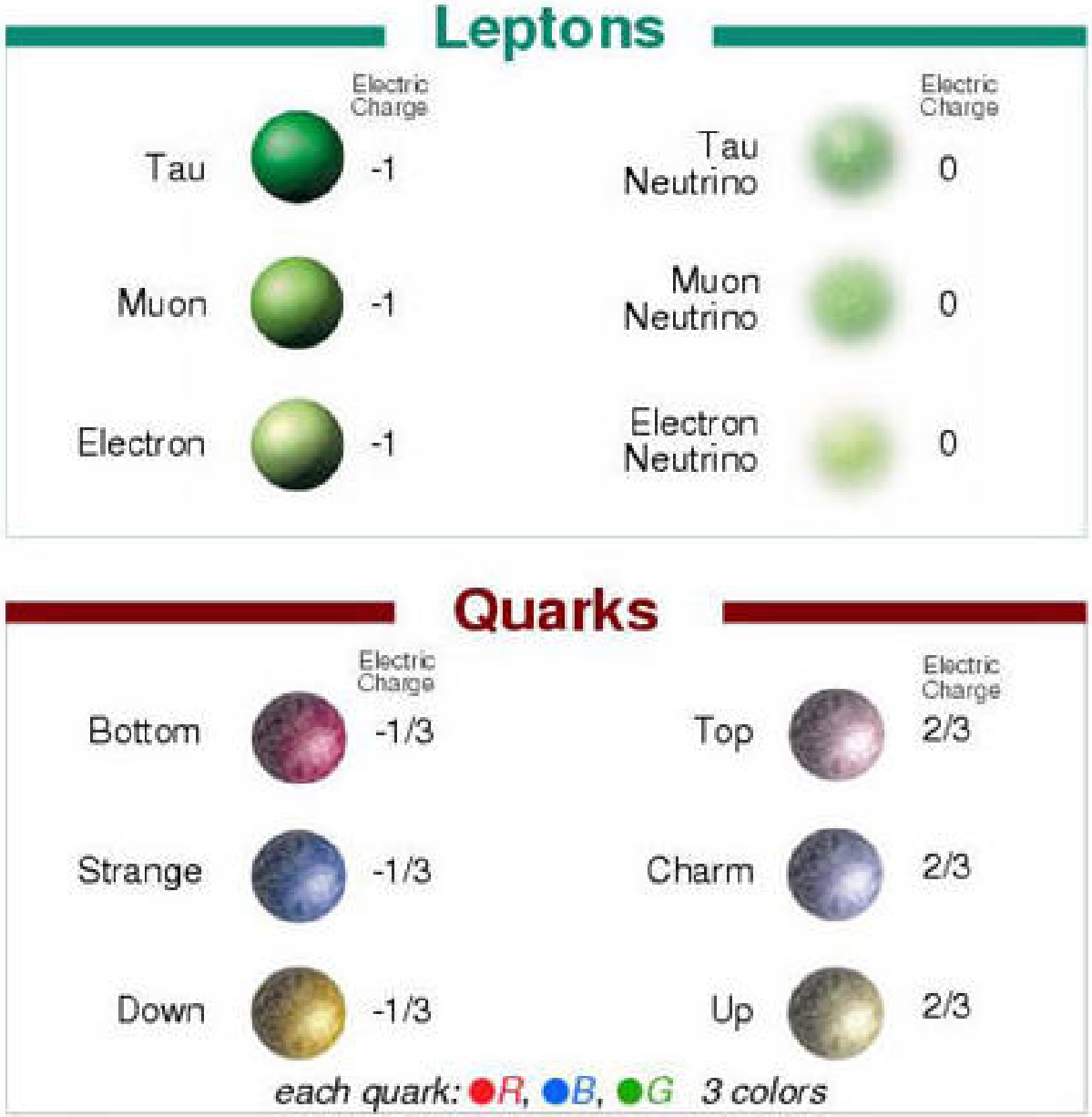


The Large Hadron Collider

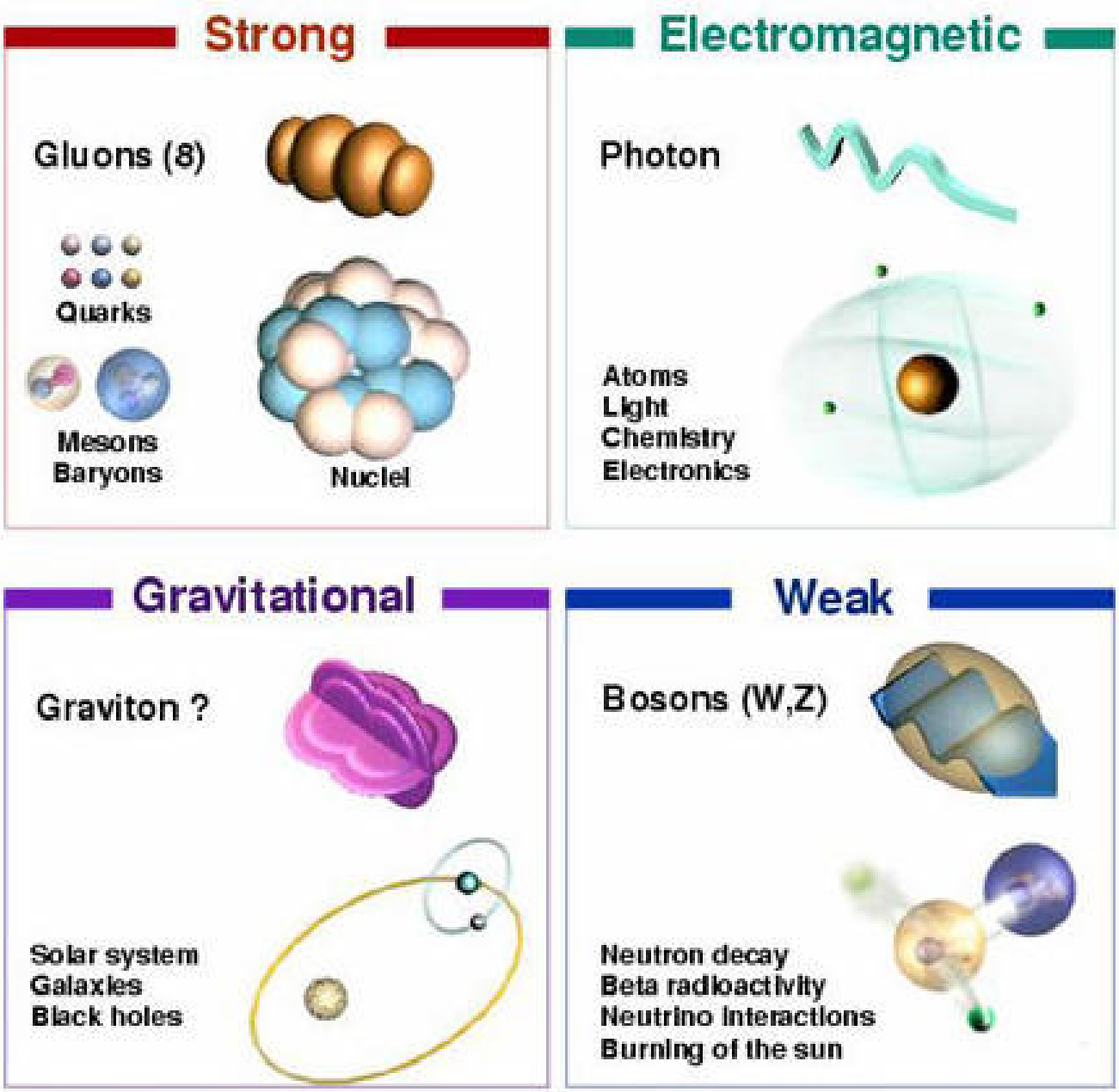
Constituents of Matter



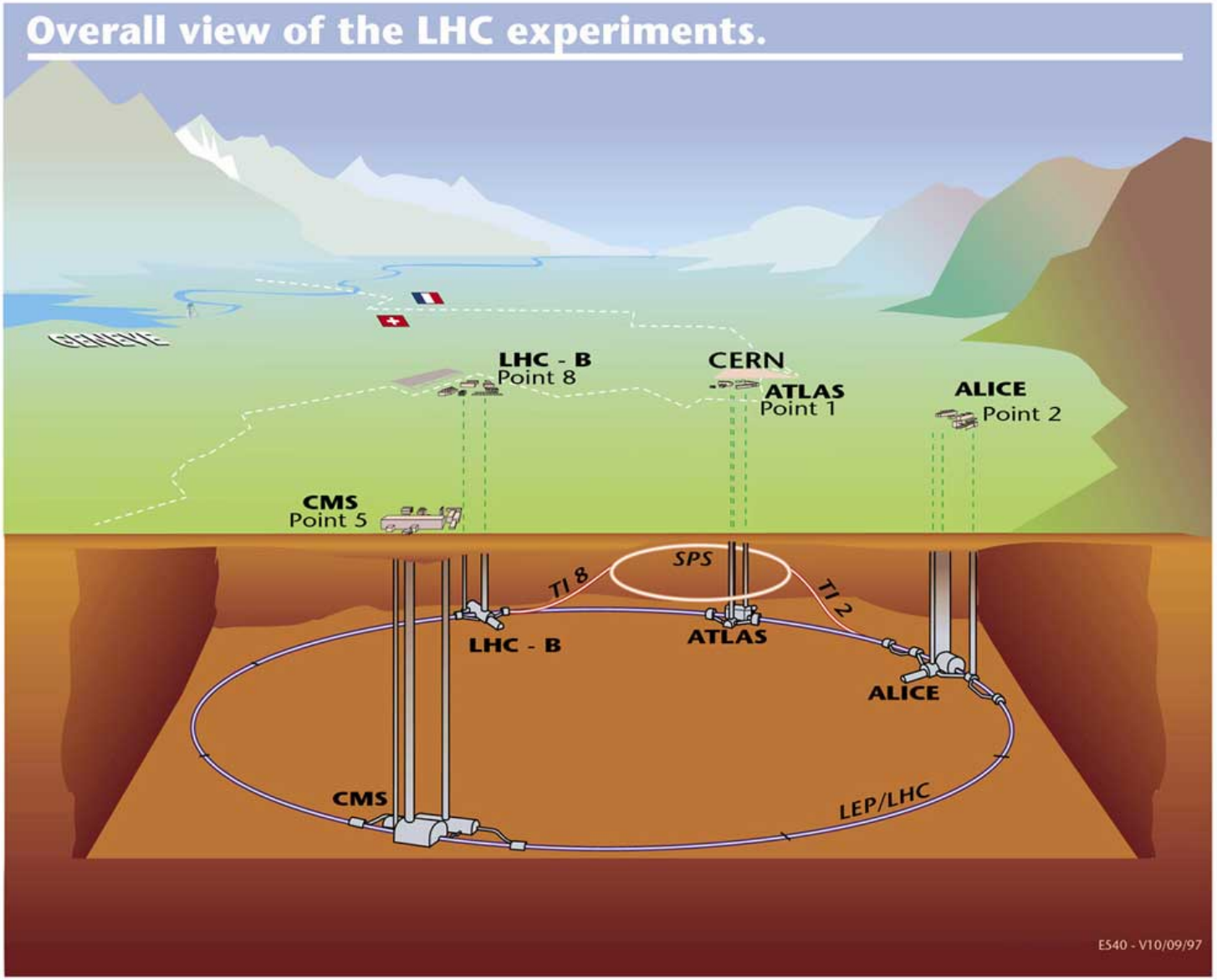
Elementary particles for matter (fermions)



Elementary particles for forces (gauge bosons)



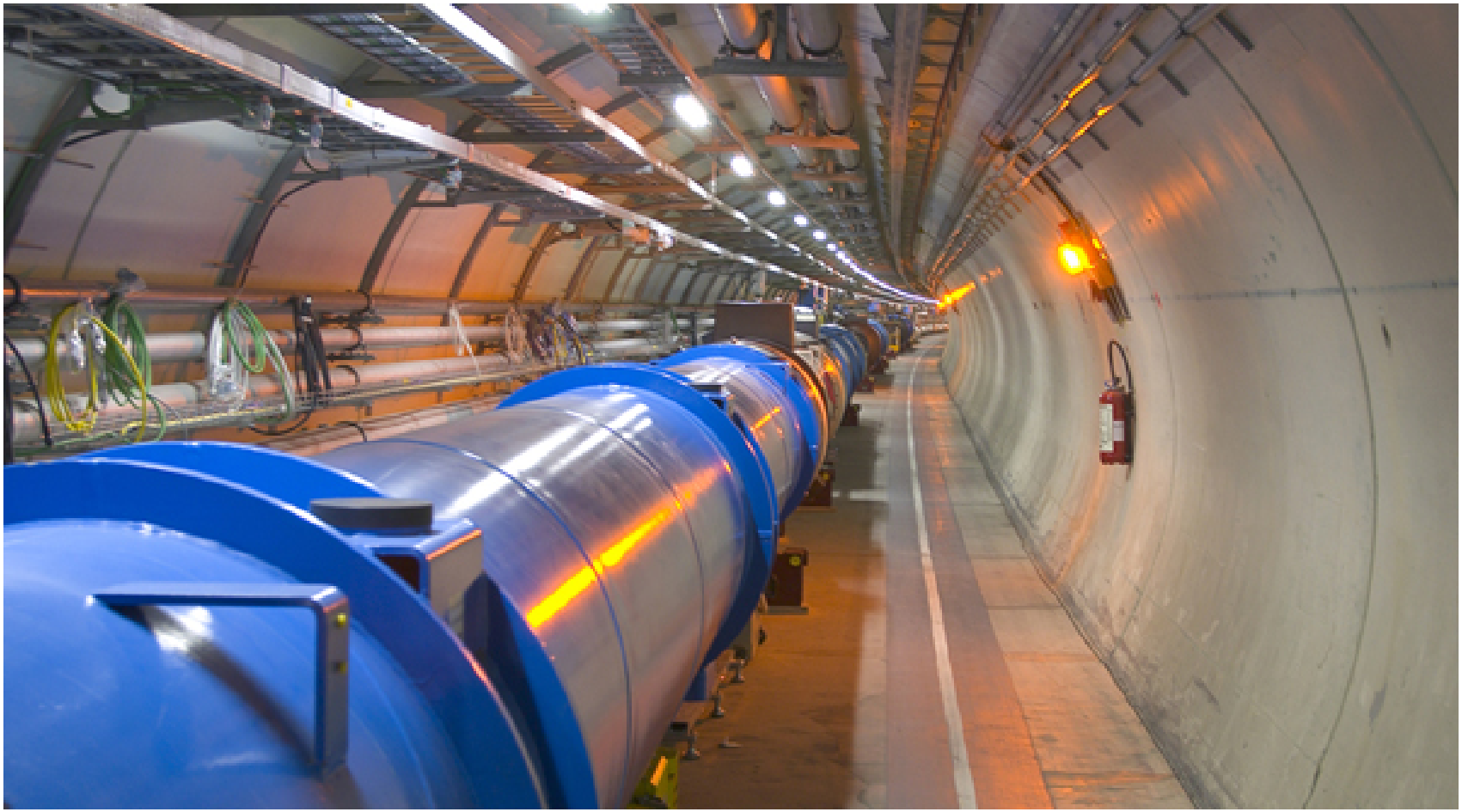
Still on the run


Overall view of the LHC experiments.
GENEVE
LHC - B
Point 8
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 8
TI 2
LHC - B
ATLAS
ALICE
CMS
LEP/LHC
ES40 - V10/09/97

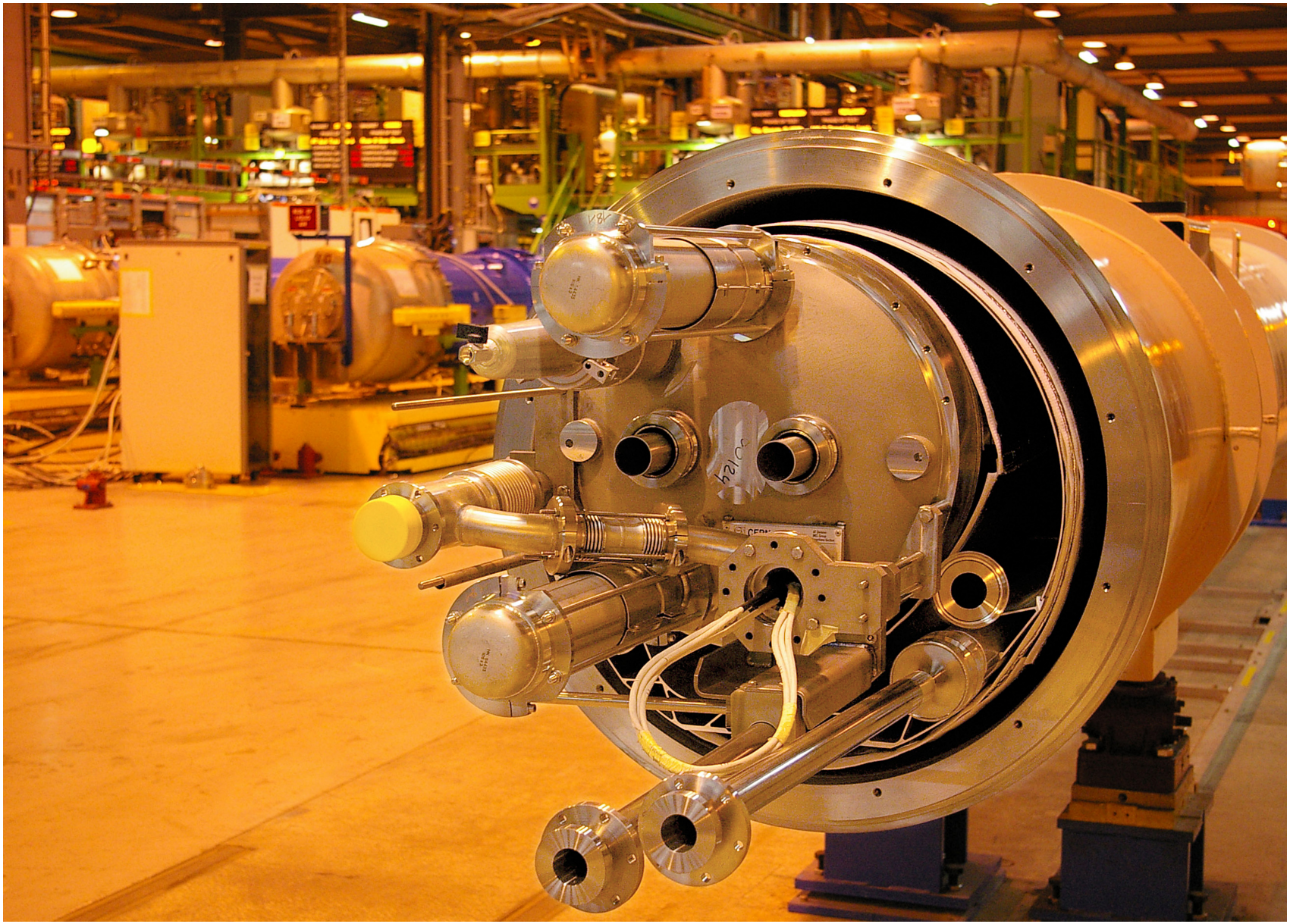
LHC — Some numbers

- 27km circumference
- 50–175m below the surface (Switzerland/France)
- 2 opposite beams of protons
- 7TeV each
- 1232 dipole + 392 quadupole superconducting magnets
- 96t liquid helium at 1.9K
- 2808 bunches with 11,000 revolutions/s (10^{-9}g H with 724MJ i.e. 173kg TNT)
- 1 bunch crossing each 25ns
- Two general purpose detectors (ATLAS, CMS), two specialised (ALICS, LHCb)
- >10,000 scientists from >100 countries
- US\$ $9 \cdot 10^9$ (incl. $3 \cdot 10^9$ Euro for accelerator $+7 \cdot 10^8$ Euro for experiments)

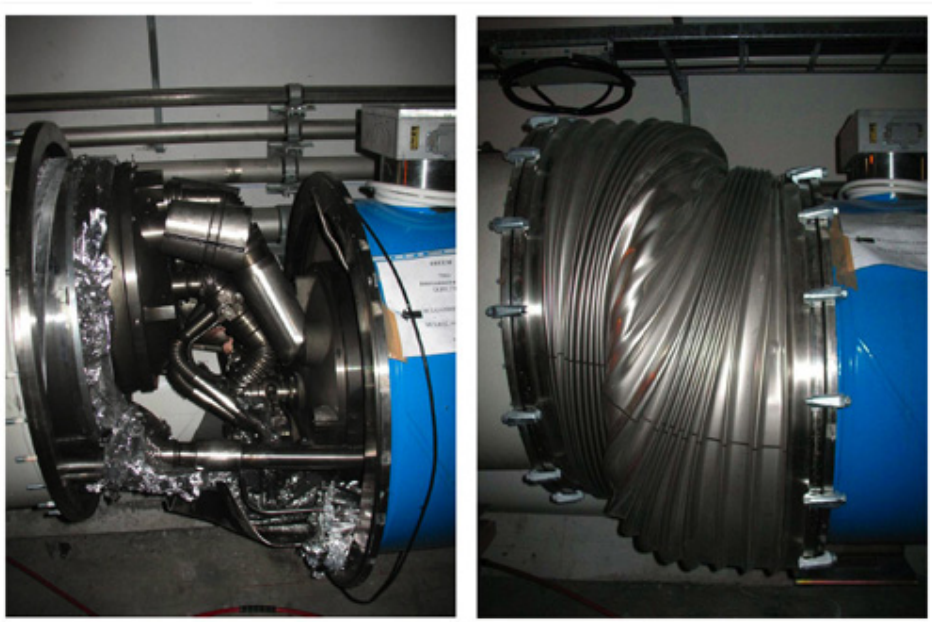
Like a subway tunnel



A magnet



After the first nine days in 2008



Faulty electrical connection between magnets
100 magnets quench (100K temperature rise), 53 damaged
6t liquid helium lost
14 months recovery time

What we hope to see

- The Higgs particle
- Supersymmetric partners
- Dark matter?
- Extra dimensions?
- Mini black holes?
- Surprises???

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Will it destroy the earth?

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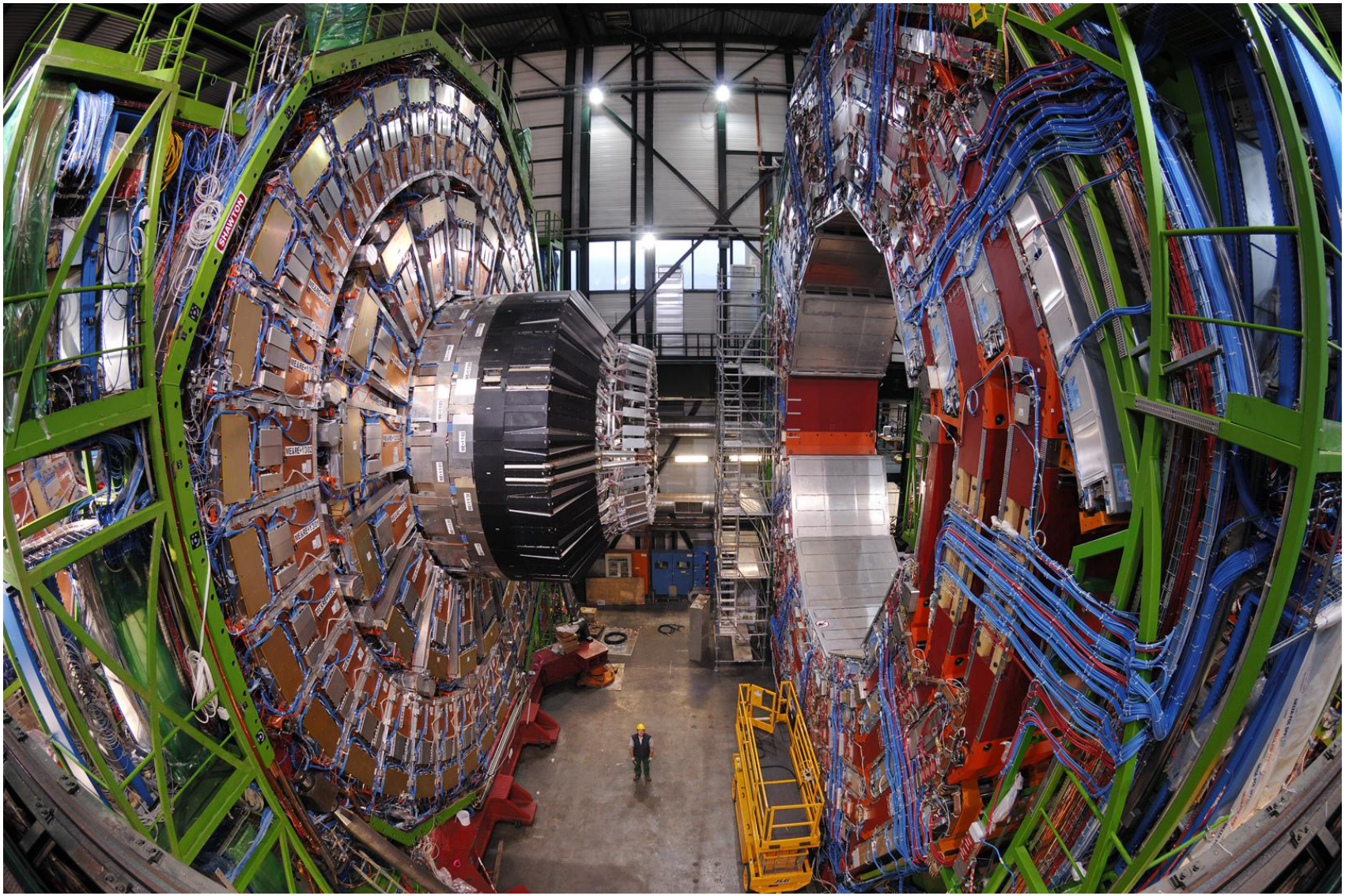
- Surprises???

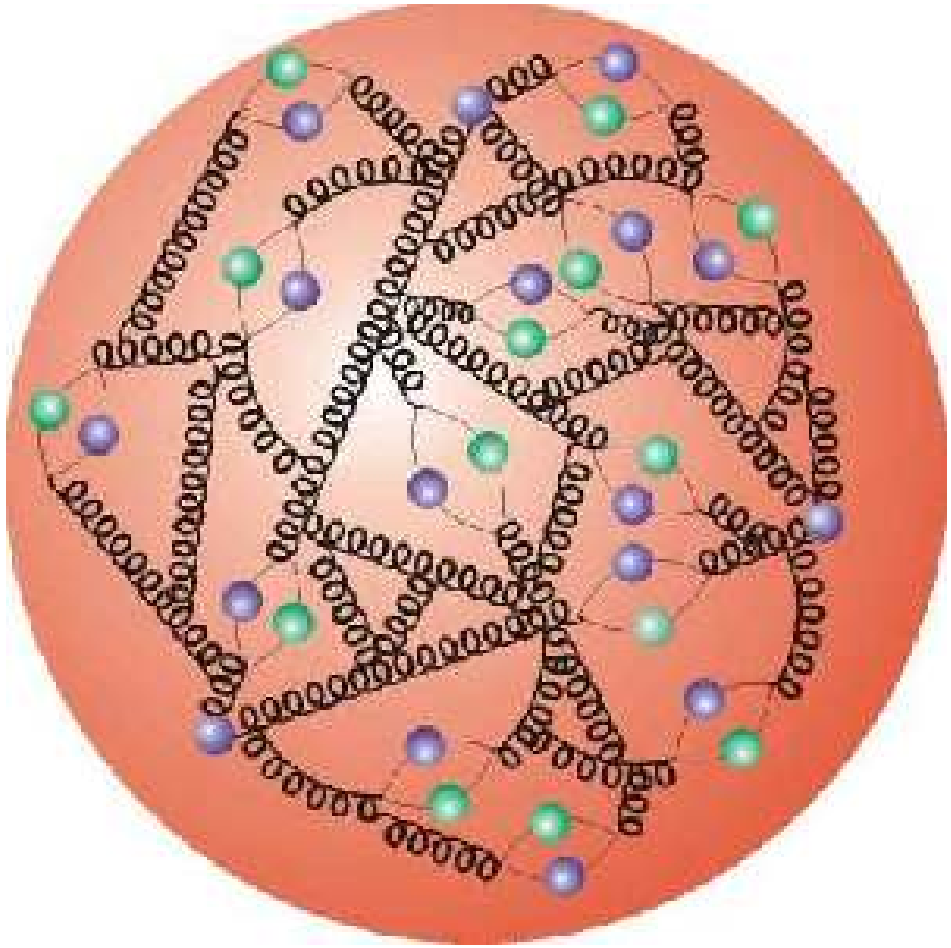
Will it destroy the earth? NO

The detectors

CMS on surface

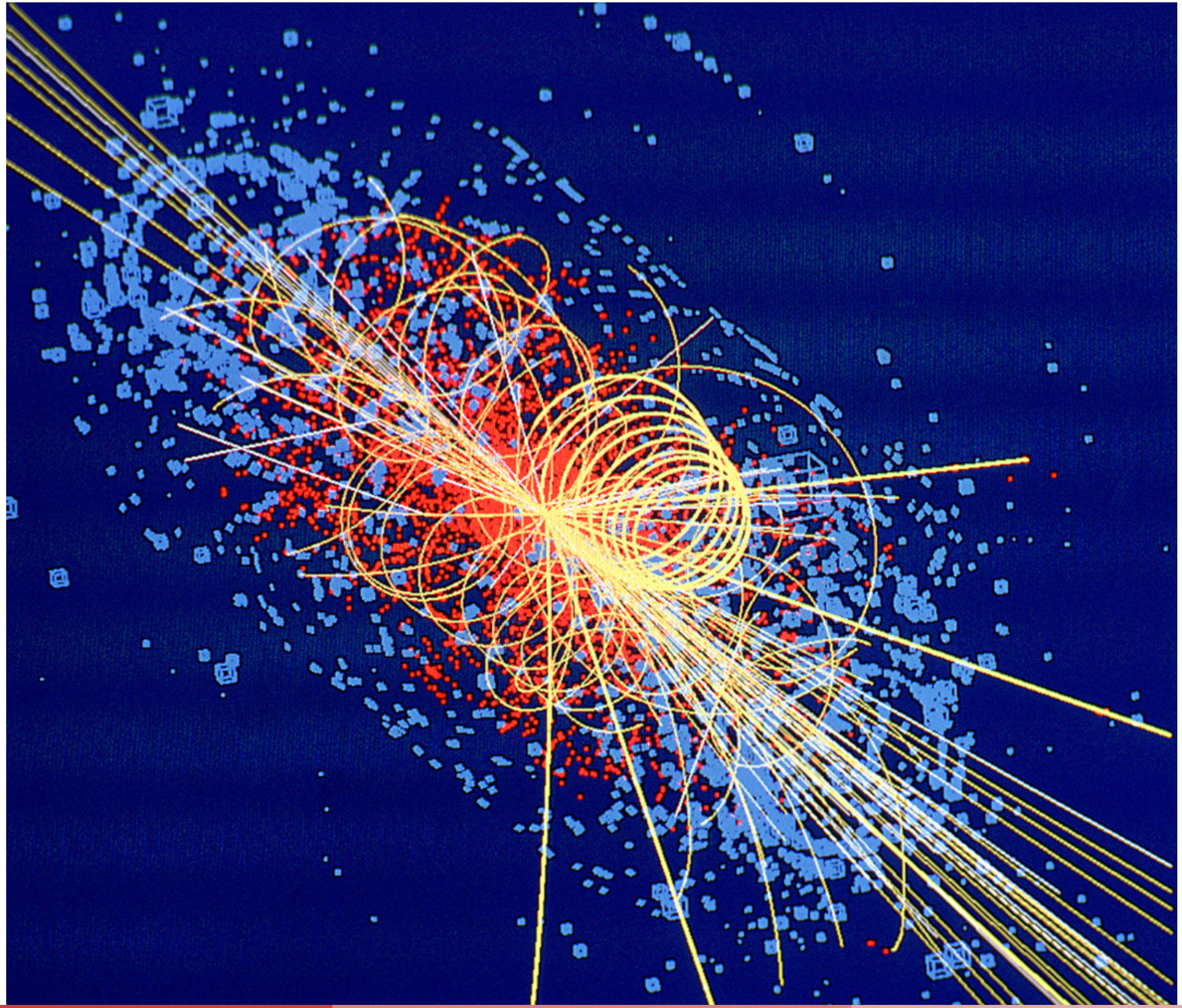


A closer look at the proton

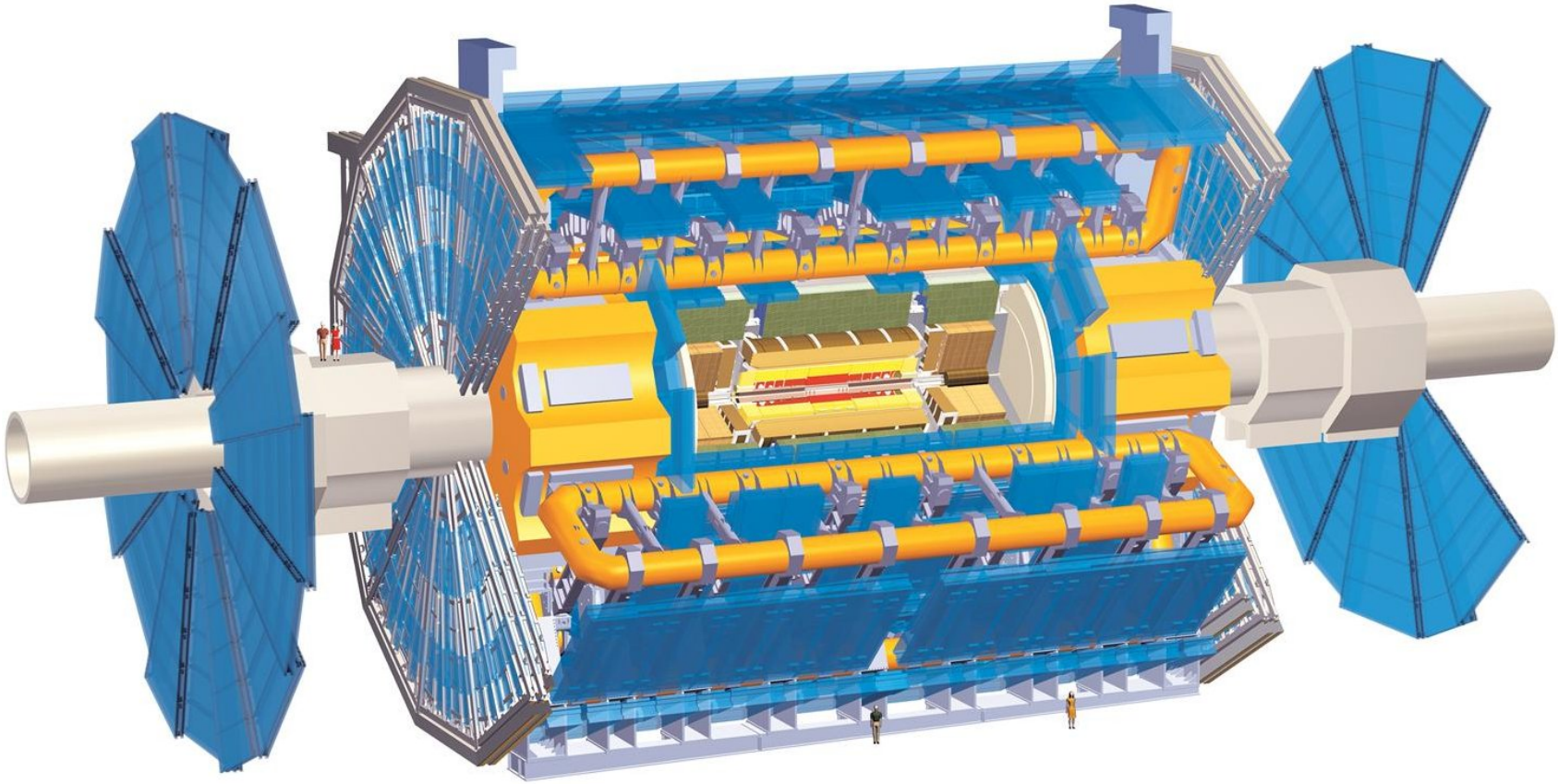


A closer look at the proton

Debris of pp-collision including a Higgs (simulated)



ATLAS schematics



→flash animation

Data reduction at CMS

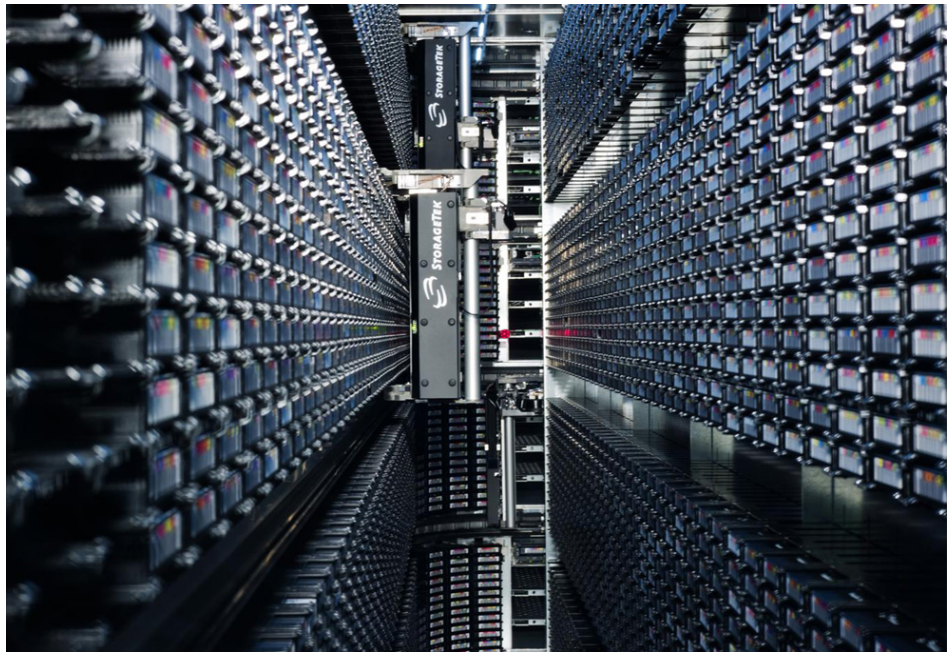
Bunch crossings every 25ns (40MHz) with ≈ 17 events each $\Rightarrow$ 1GHz event rate

25 light-ns = 7.5m

Only 1 in 10^7 are interesting (100Hz)

Complete detector readout is about 1MB (zero suppressed) $\Rightarrow$ 15PB/year

Two reduction stages: L1 and HLT



Level 1 Trigger

- Custom electronics
- Pipeline storage for 3.2μs (128 beam crossings)
- One decision every 25ns, 1μs to decide
- Only local information, calorimetry and muons
- Event rate reduced to 100kHz (1 in 10^4)

High level trigger

- Complete read out of 700 Front-End Electronic Modules
- Partial event reconstruction
- Up to 1s per event
- Off the shelf hardware (farm O(1000) PCs)
- RAM is fast enough
- 700:1000 switching at 100GB/s
- Event tagging for off-line analysis in GRID
- Data production 10TB/day

Spin offs

The Teflon pan of particle physics are

Spin offs

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- industrial scale superconducting magnets

Spin offs

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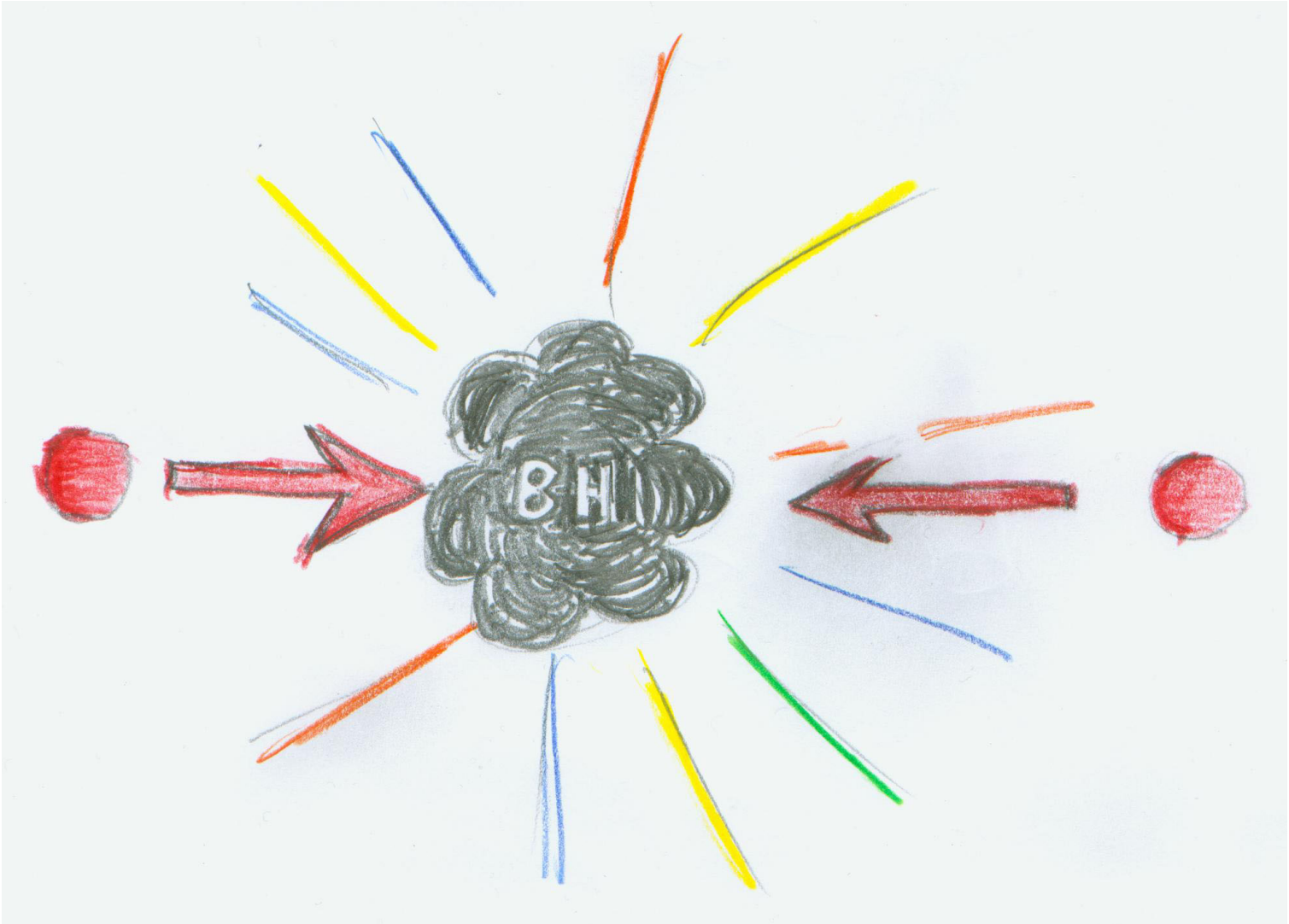
-

General Relativity — Space-time itself is dynamic

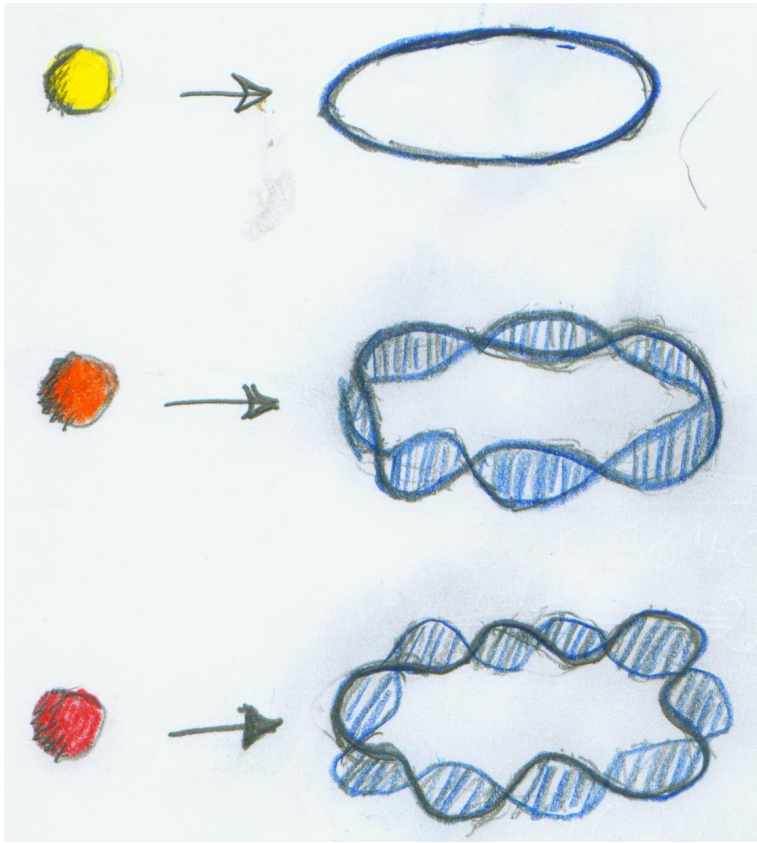
Curved space can act like a force

Space disappears at very short distances



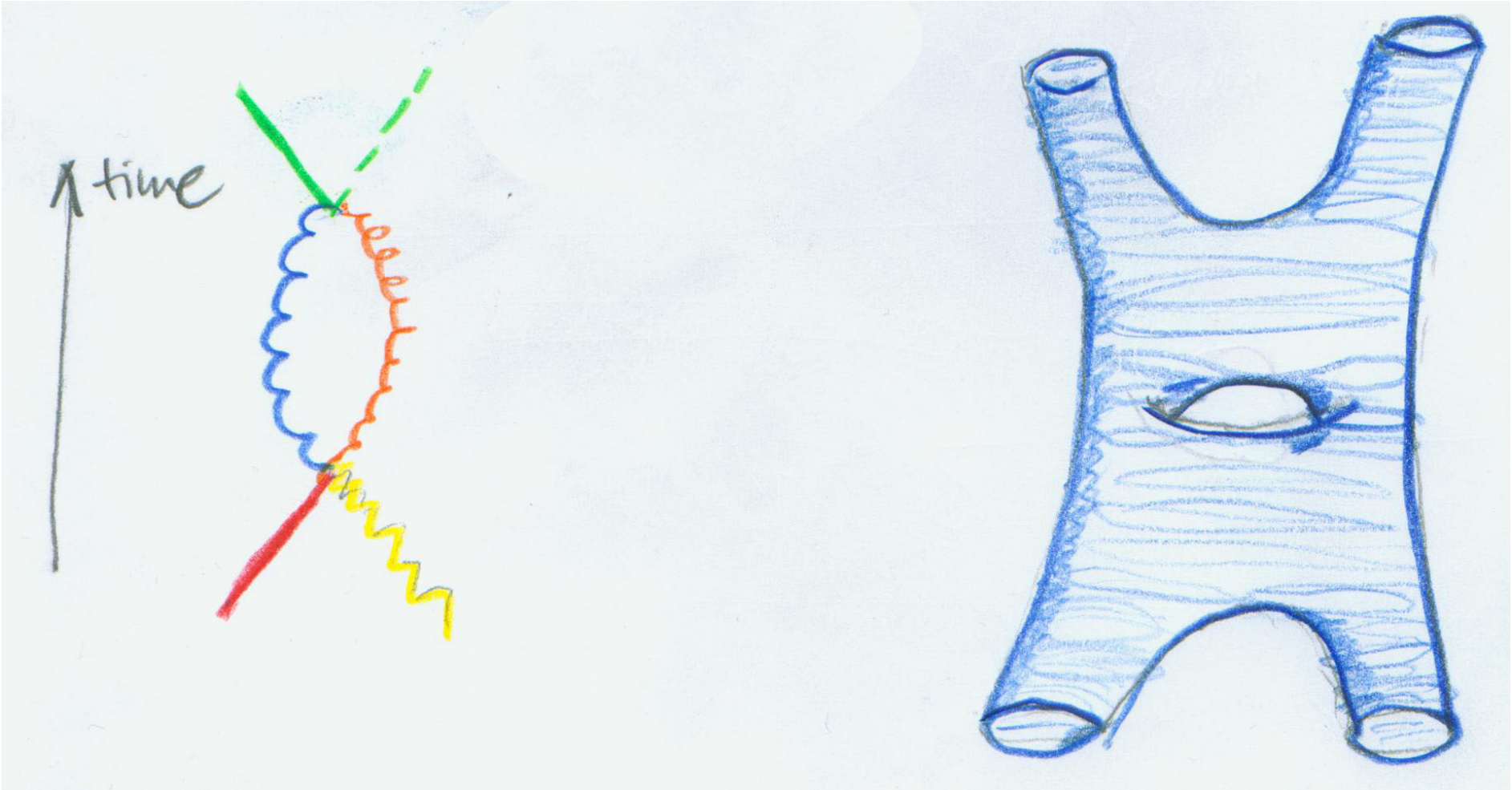
$\ell_P = 10^{-33}$m (NB Proton radius is 10^{-15}m.)

Different particles are oscillation modes of a string



The graviton (a massless spin 2 particle) is always present.
String Theory is a Quantum Gravity.

Collisions à la String



Extra dimensions

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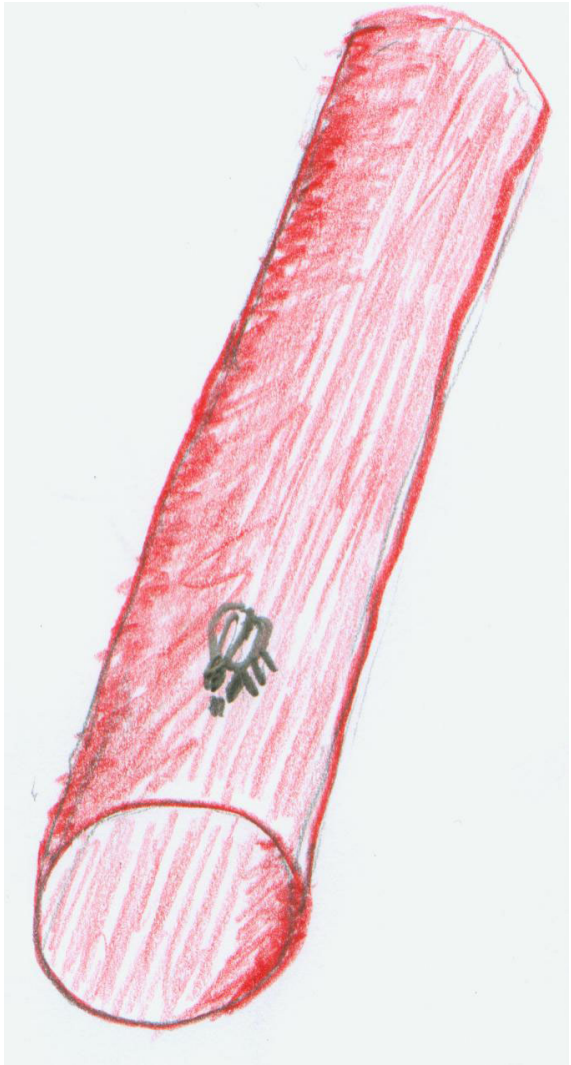

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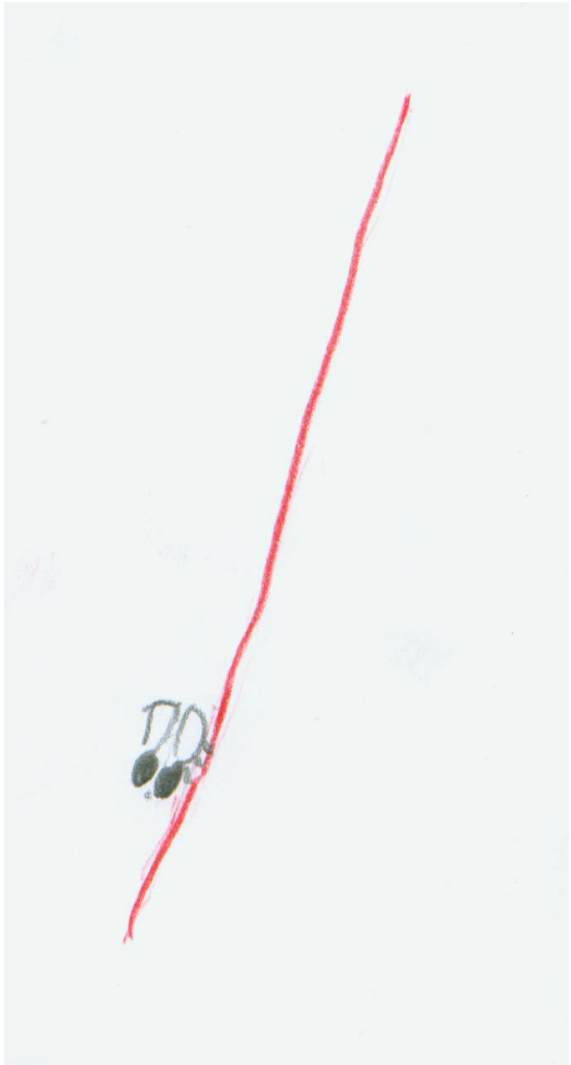

Compactification

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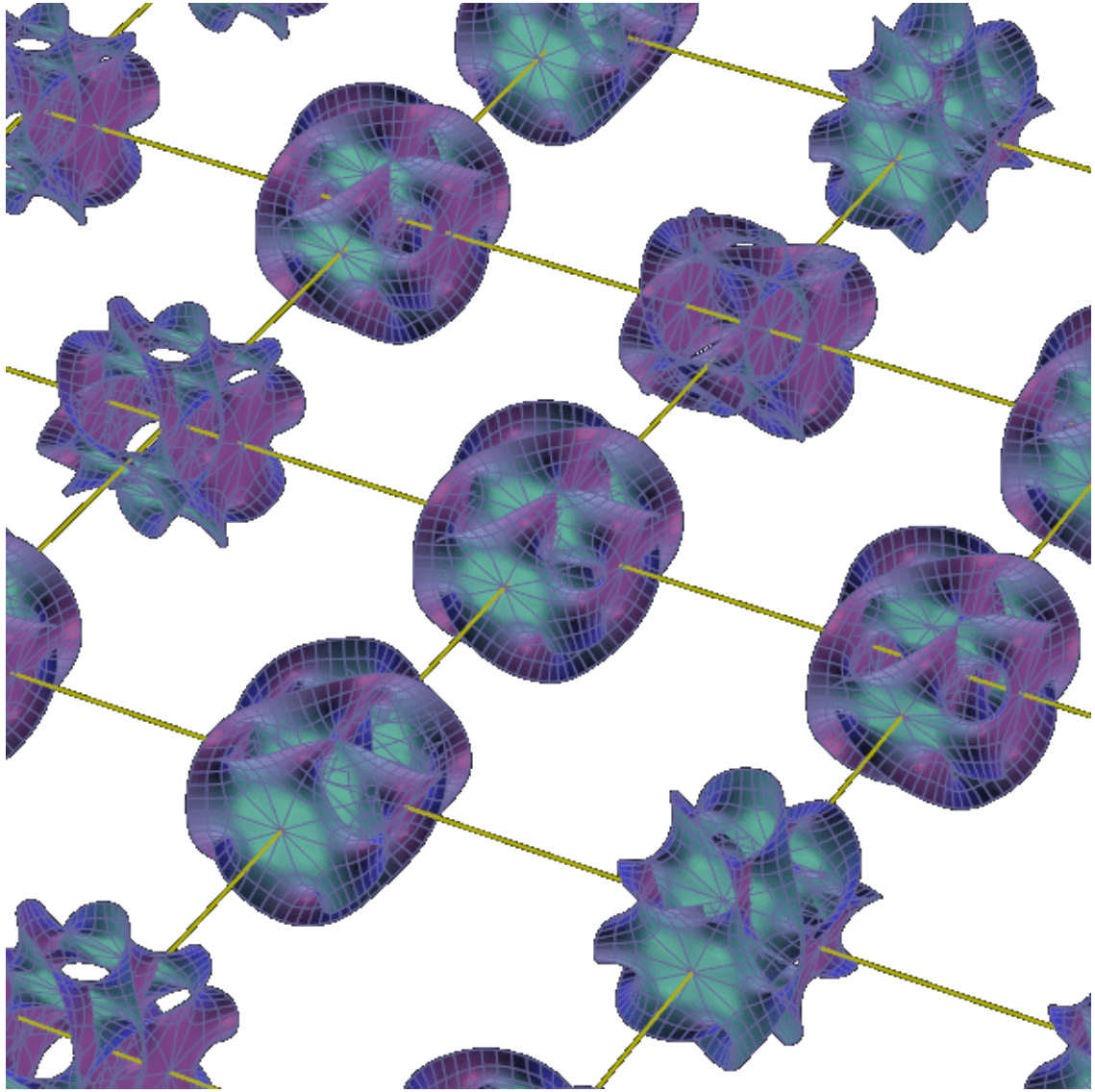

The String Landscape

10^{500} solutions of string equations of motion.

Details of the compactification space determine the excitations of the string and thus the "low energy" particle spectrum.

Open Source Physics?

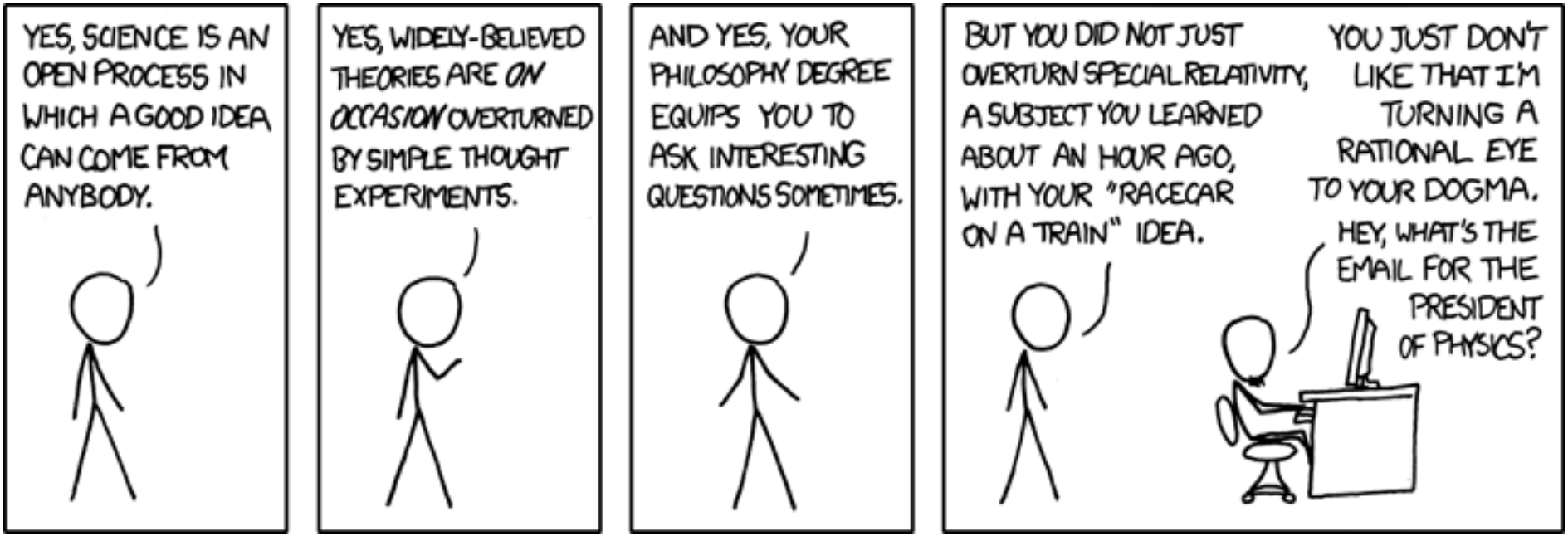

Image Credits

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