How far do we understand our Universe at this moment?

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This lecture, presented in IEDC Bled at 04. 07. 2018, is intended for curious people who would like to understand where we are placed and what are laws which govern our universe and our lifes.

At the twenty first annual workshop entitled "What Comes Beyond the Standard Models?" which takes place at Bled, Slovenia, since1998, this year from 23 June - 1 July 2018

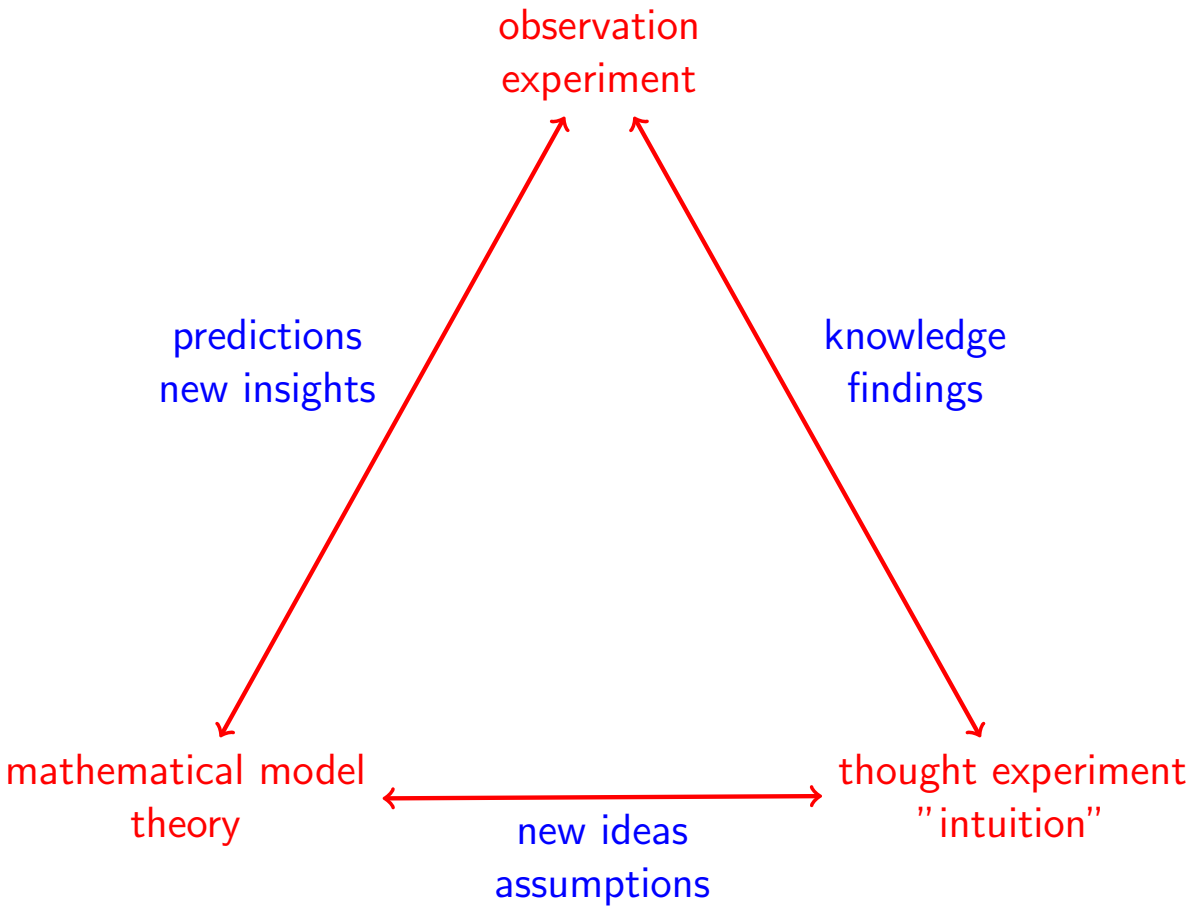
June, **2018**

How do we gather knowledge - understanding -

- **about the laws, which govern the smallest constituents of Nature**
- **and correspondingly the whole our Universe and might be universes?**
- **How do we learn about the space-time in which we live?**

- We observe.
- We make experiments.
- We make thought experiments, leading to new questions, new ideas.
- We make mathematical models, which cover the so far made discoveries, findings, thoughts, ideas.
- The models make predictions.
- We check predictions by experiments.

We repeat this circle again and again, with more and more knowledge and more and more and more intuition.

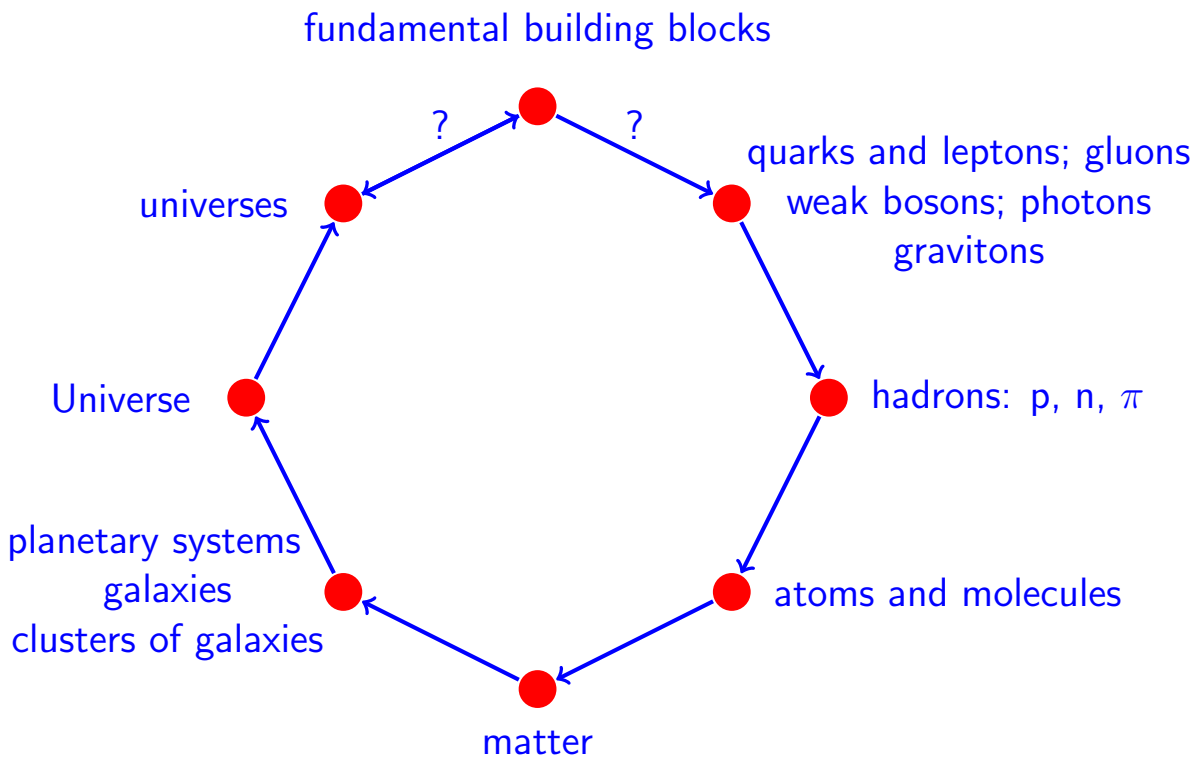

observation
experiment
predictions
new insights
knowledge
findings
mathematical model
theory
thought experiment
"intuition"
new ideas
assumptions

We try to understand:

- What are elementary constituents and interactions among constituents in our Universe, in any universe?
- Can the elementary constituent be of only one kind? Are the four observed interactions — gravitational, elektromagnetic, weak and colour — of the common origin?
- Is the space-time the so far observed (3 + 1)? Why (3+1)?
- If not (3 + 1) may it be that the space-time is infinite?
- How has the space-time of our universe started?
- What is the matter and what the anti-matter?

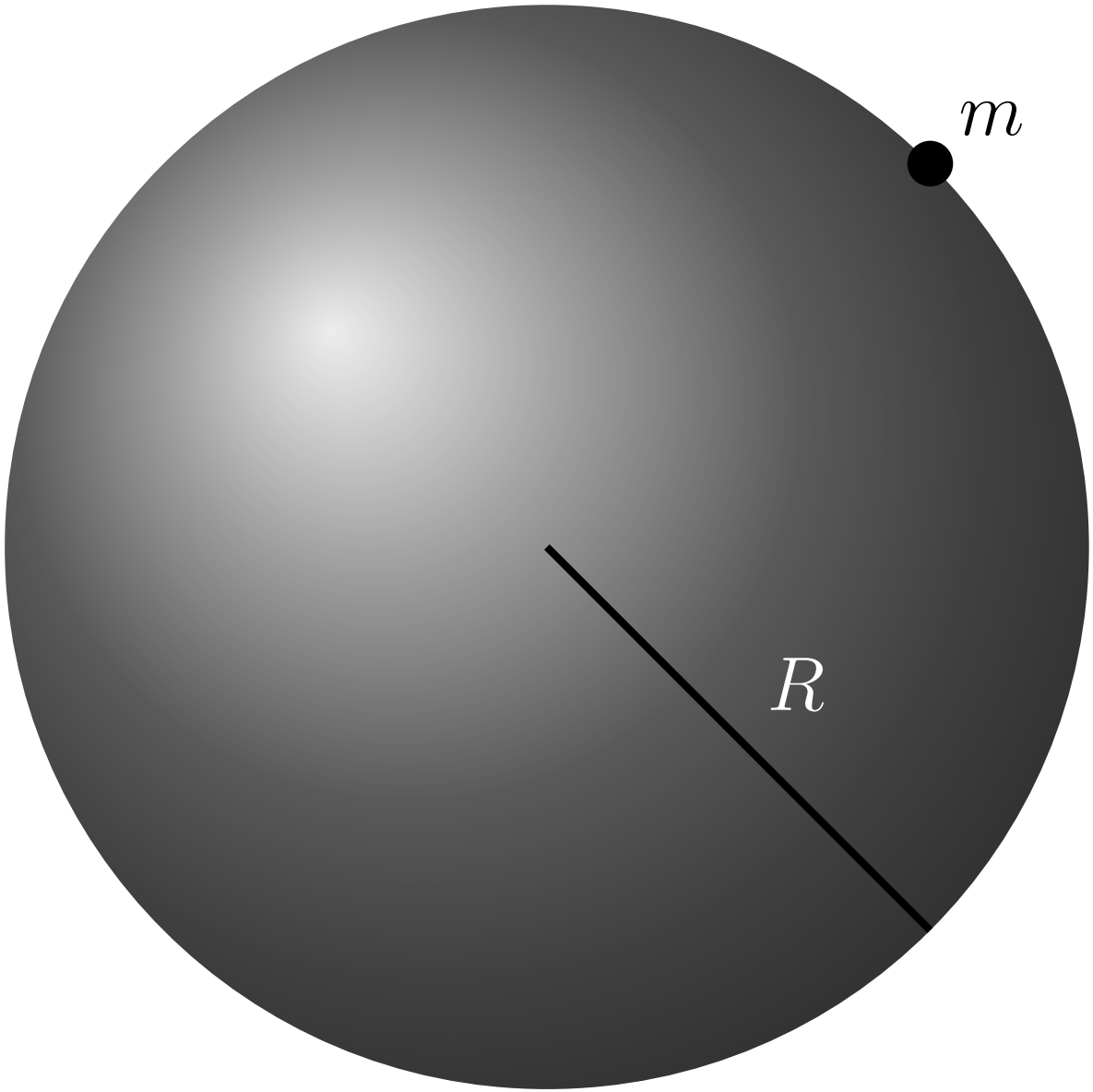
- **How has the life started?**
- **Where do ideas, thoughts, recognitions, findings, understanding originate?**

Questions about the elementary building blocks and cosmology have never been so connected as they are now.



Knowledge was created slowly, step by step, although some of the steps were for a long time present and evident. Like:

- That our Earth is round. Every sailor knew that.
- That our Earth is rotating.
- That Earth is running around the Sun.


m
R

- We all can derive the Einstein equations for the universe from the Newtons laws:

$E = T + V$.

E is the total energy of a body with mass m.

T is its kinetic energy $\frac{m(\frac{dR}{dt})^2}{2}$,

where R **is its position in the system of massive bodies.**

V is the energy of m caused by the the gravitational force of all the masses M**, forming the system:**

$V = -G\frac{mM}{R}$.

$G = 6.67 \cdot 10^{-11} kgm^2 sec^{-2}$ **is the measured gravitational constant.**

- **Correspondingly** $E = \frac{m(\frac{dR}{dt})^2}{2} - G\frac{mM}{R}$.
- **If we multiply this equation by** $\frac{2}{mR^2}$**, rename** $k = -\frac{2E}{m}$**, call** $\rho = \frac{3M}{4\pi R^3}$**,**
  we end up with the equation of motion for the isotropic and homogeneous universe in the non relativistic limit.

$$\mathbf{(\frac{dR}{dt})^2 + \frac{k}{R^2} = \frac{8\pi G\rho}{3}.}$$

- $M_{Pl}^2 = \frac{\hbar c}{G}$, $\quad \Delta t_{Pl} = \frac{\hbar c}{c M_{Pl} c^2}$

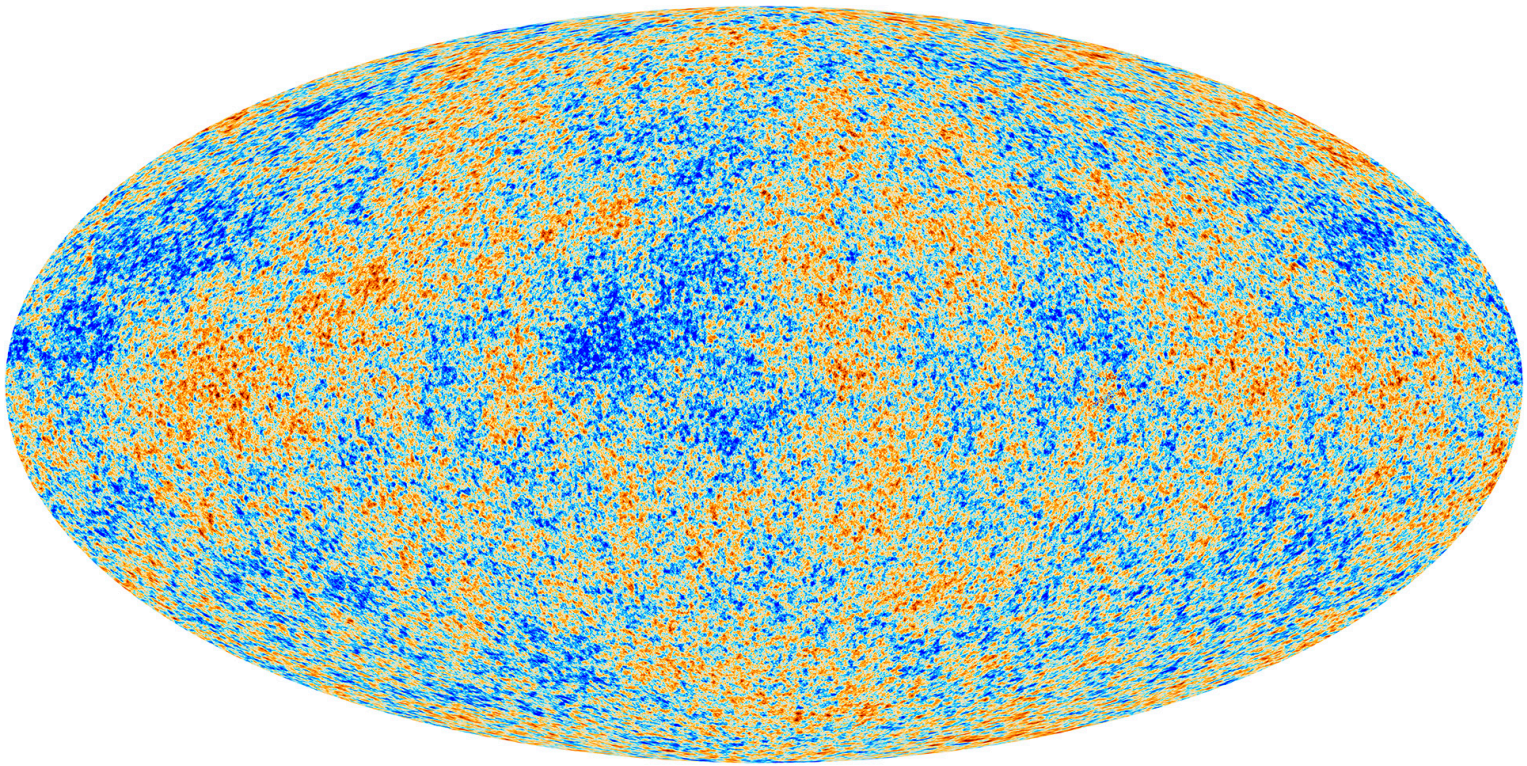
The hystory of our universe

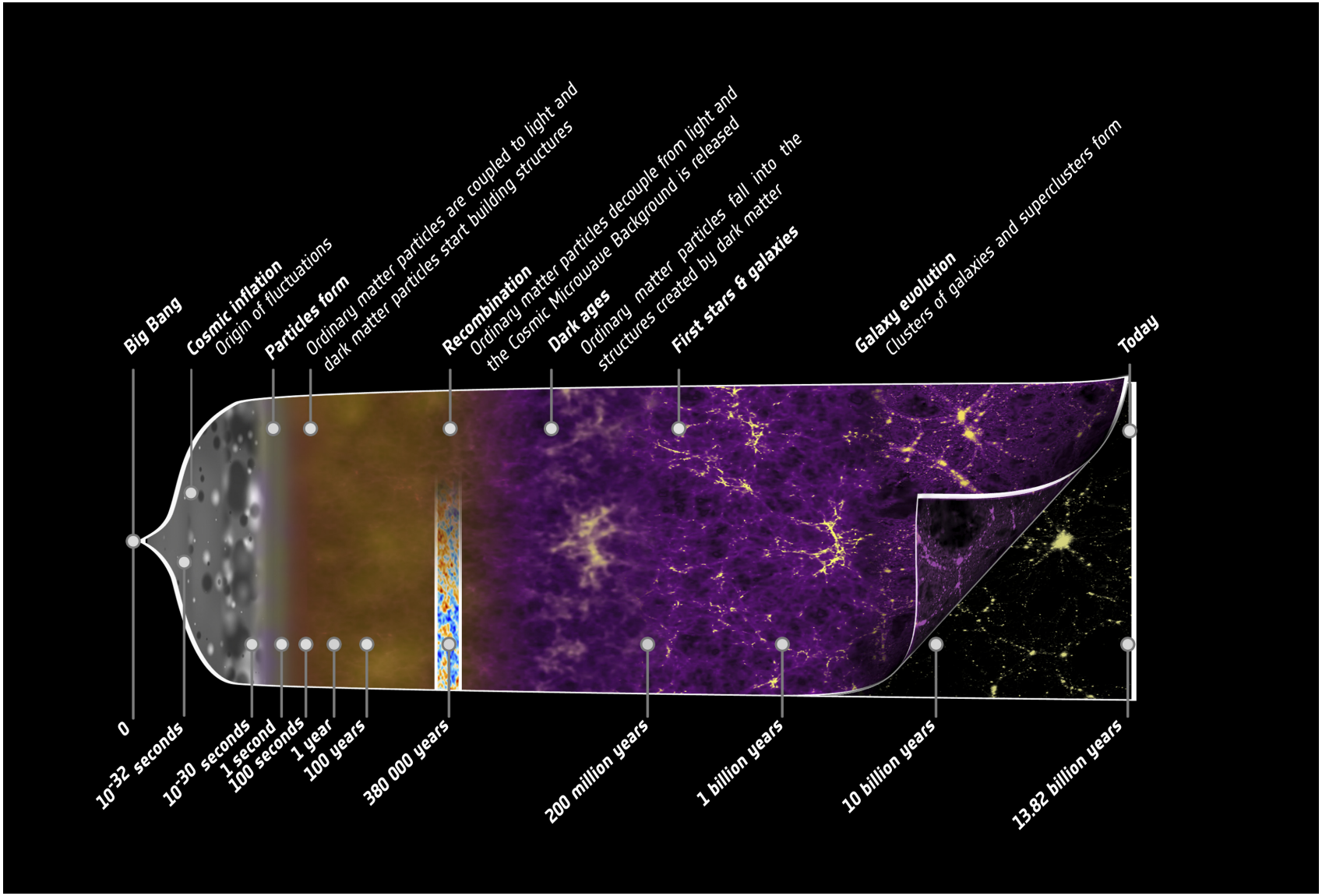
- 10^{-43} s... **The history of our universe started with the Big Bang, as we can guess from models and experiences when treating quantum systems and from observations of properties of our universe.**
  o We have no knowledge about the dimension of space-time at the Big Bang. (Was it larger than (3+1)? Was it ∞?
- **The theory, supported by very demanded experiments** with scattering particles at high energy, up to 14 TeV (13,5 TeV so far) (**CERN**), leads us to conclude that **elementary constituents** are (very probably) **quarks and leptons**, **interacting** with **at least four kinds of interactions**: **colour, weak, electromagnetic and gravity.**
- $10^{-5}s$ ... **Quarks and leptons formed hadrons — p, n, ..**

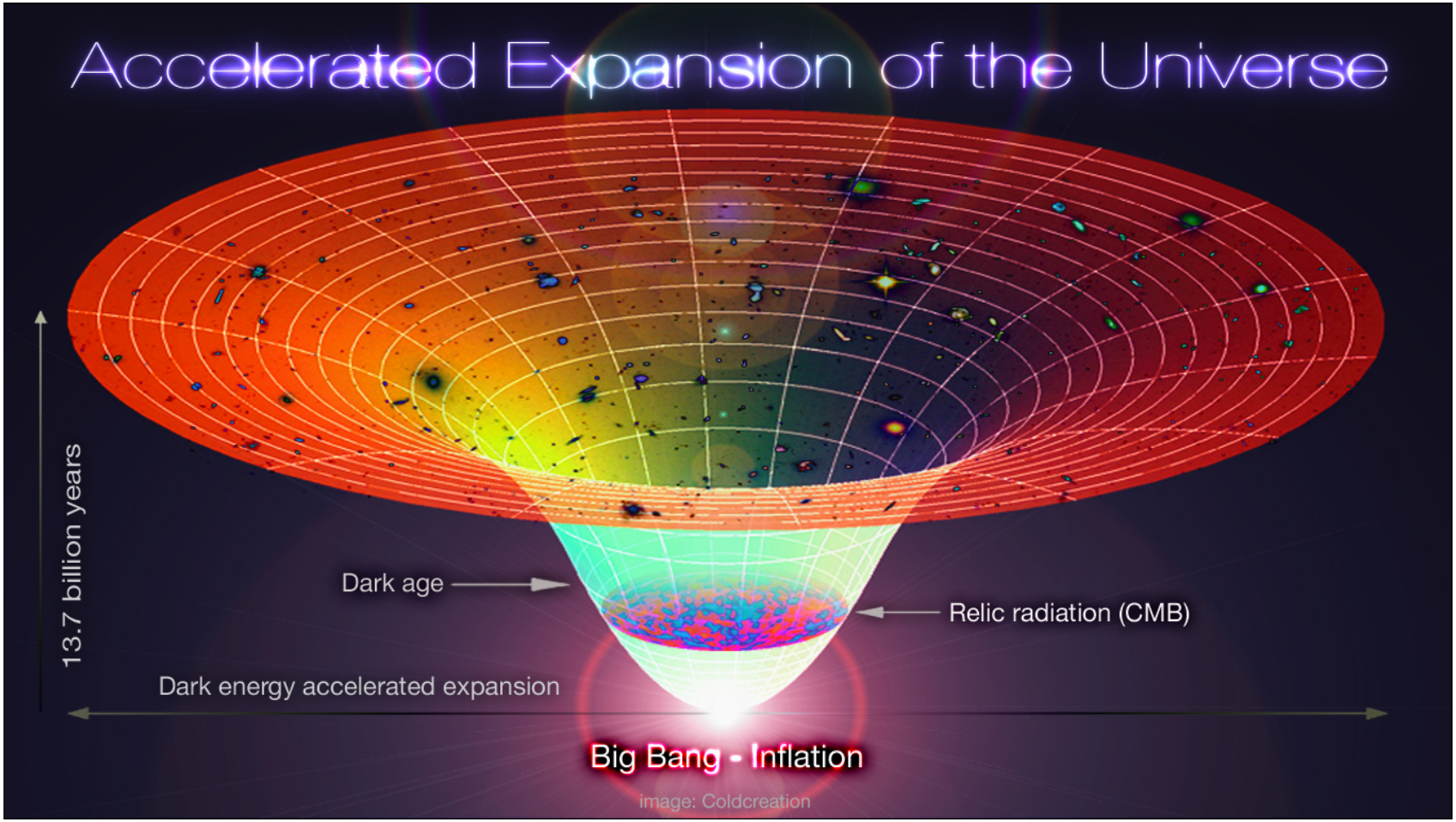
- 3 **min... Protons and neutrons made atomic nuclei.**
- 380 000 **years... Nuclei and electrons made atoms. Our universe became transparent.**
- 10^9 **years... Stars and galaxies started to be formed.**
- $13.8 \cdot 10^9$ **years... Present time, dominated by dark energy** (antigravity) **(70%), dark matter (25%), ordinary matter (5%) (0.03% of heavy elements (anything other than hydrogen and helium), 0.3% neutrinos, 0.5% stars, 4% free hydrogen and helium.**

- **We do not know whether the observed electromagnetic, weak and colour interactions, the strength of which are so different at low energies, and are becoming more and more equal to higher energies we go, were together with gravity only one interaction**.
- **We do not know where from** the **scalar field**, **needed to cause inflation after** the **Big Bang** (needed for explaining the homogeneity and isotropy of the universe and other observations), **originates.**
- **We are trying to understand Nature through theories and experiments and intuition ...**
- **Is the low of nature elegant and simple, or it is complicated?**

9-year W(ilkinson)M(icrowave)A(nisotropy)P(probe) image (2012) of the cosmic microwave background radiation across the universe, $10^{-5} - 10^{-4}$, 2.7^o K, stared when the universe became transparent.




Big Bang
Cosmic inflation
Origin of fluctuations
Particles form
Ordinary matter particles are coupled to light and dark matter particles start building structures
Recombination
Ordinary matter particles decouple from light and the Cosmic Microwave Background is released
Dark ages
Ordinary matter particles fall into the structures created by dark matter
First stars & galaxies
Galaxy evolution
Clusters of galaxies and superclusters form
Today
0
10-32 seconds
10-30 seconds
1 second
100 seconds
1 year
100 years
380 000 years
200 million years
1 billion years
10 billion years
13.82 billion years


Accelerated Expansion of the Universe
13.7 billion years
Dark age
Relic radiation (CMB)
Dark energy accelerated expansion
Big Bang - Inflation
image: Coldcreation

- **Without the theory we would not be able to explain the outcomes of most experiments.**
- **Without experiments we would not be able to decide, whether the theory (theories) which we are proposing, are what "nature" obeys.**
- **Even if "nature" (to my understanding "she" does) uses (somewhere) all the mathematics, which has been and shall ever be invented (or never), we do not know, what at all are the laws and constituents of our (or any) universe without experiments.**

- **We do know equations of motion for relativistic particles, included in this simple action**

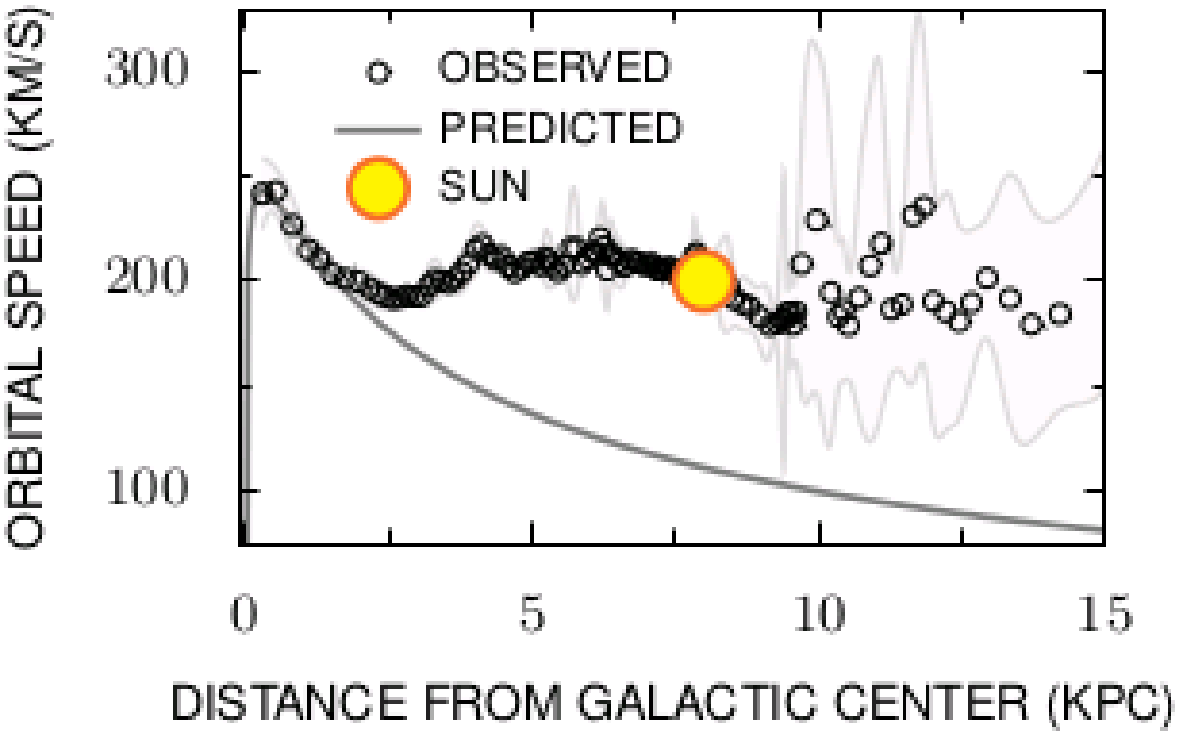
$$\mathcal{A} = \int \mathbf{d^d x}\, (\bar{\psi}\, \gamma^{\mathbf{a}} \mathbf{p_{0a}} \psi)\,,$$

in which in p_{0a} all the interactions which we observe are included.

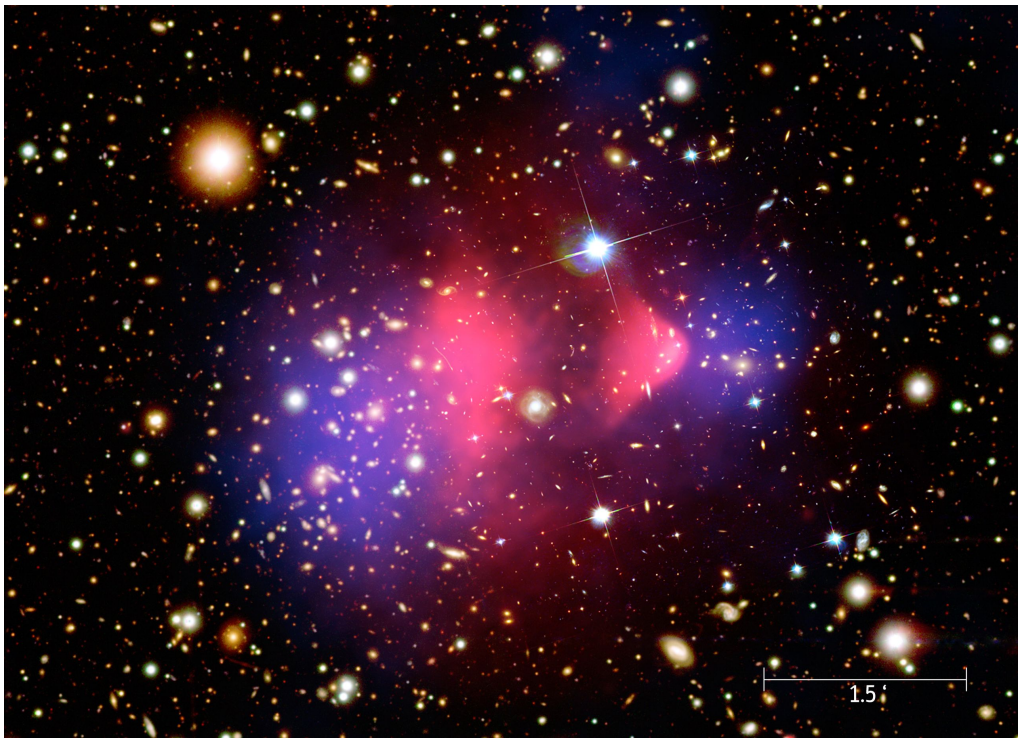
However, measurements always surprise the theory.

Fritz Zwicky in 1930's showed that the theory does not agree with what the nature manifests.

Rotation curve for the stars in the Mily Way: evidence for the existence of the "Dark matter". Blue curve is what the theory expected from the observed matter : $\frac{mv^2}{2} = \frac{mMG}{R}$



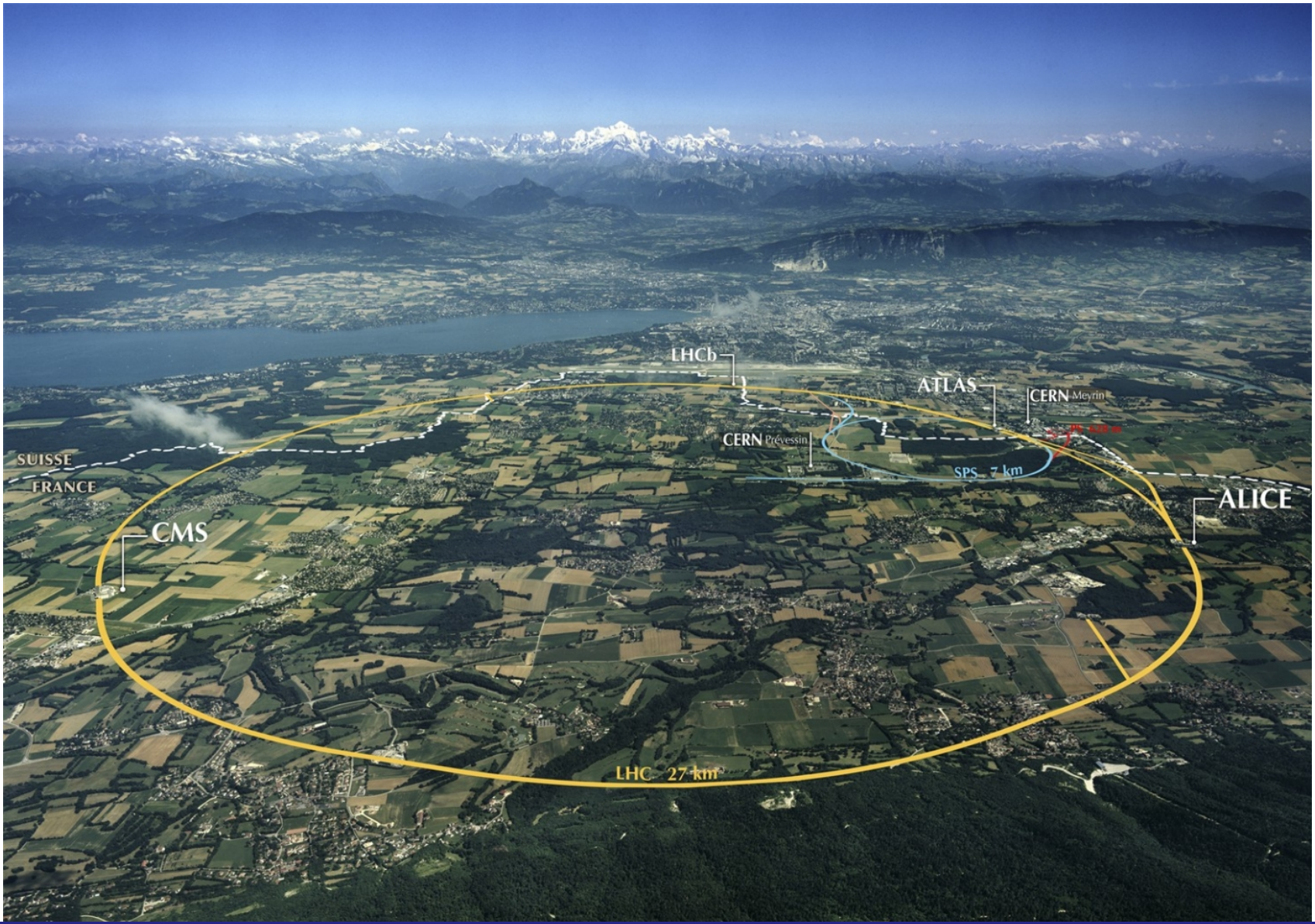
Collision of two clusters of galaxies: red represents glowing gas (X-rays) - baryonic matter, blue represents dark matter (reconstructed by measuring effects of dark matter on background galaxies - Gravity of "Dark matter" causes scattering of light)



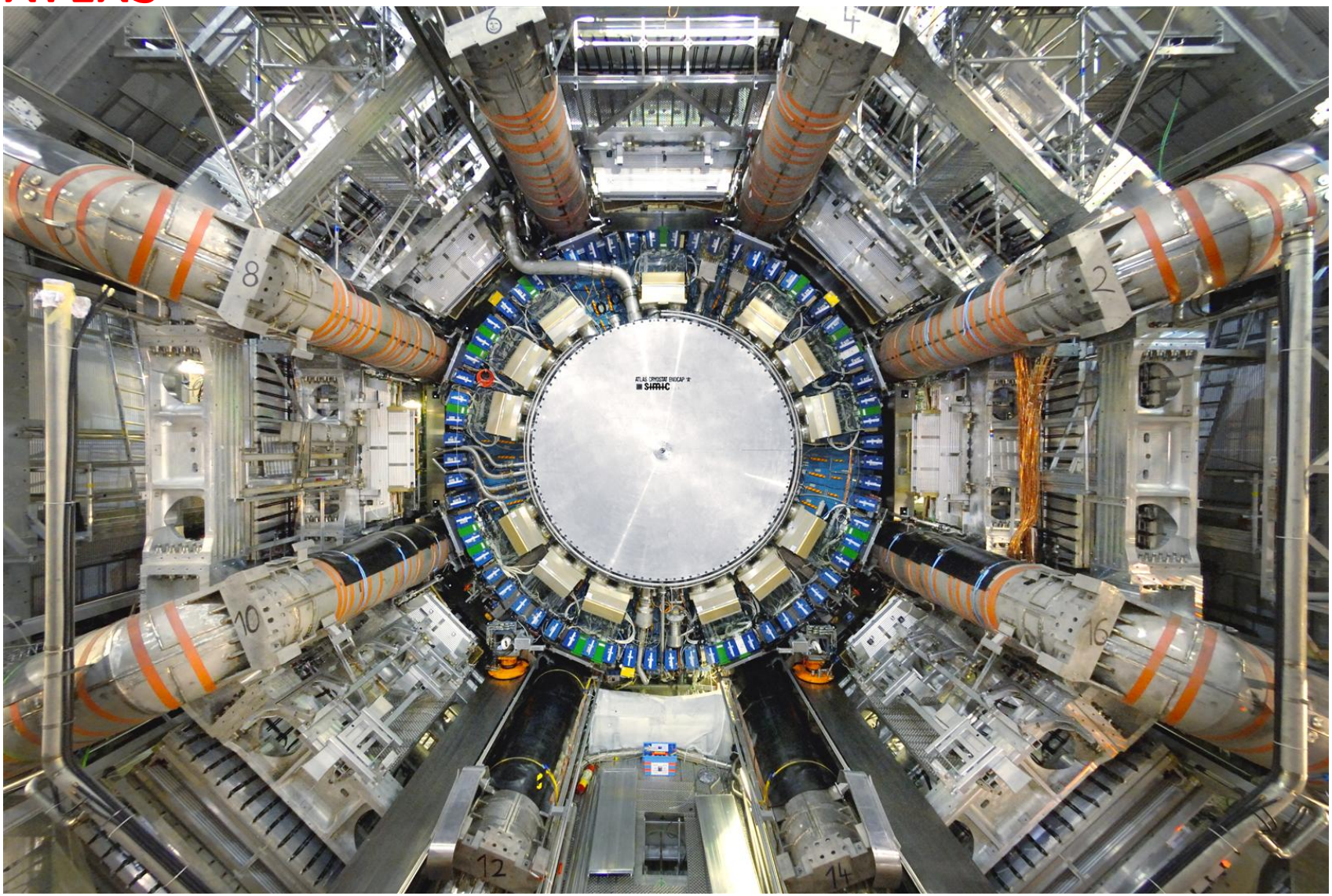
Observations and experiments check the theories and their predictions.

Observations and experiments need theory to explain experiments and observations.

L(arge) H(adron) C(ollider), CERN



ATLAS



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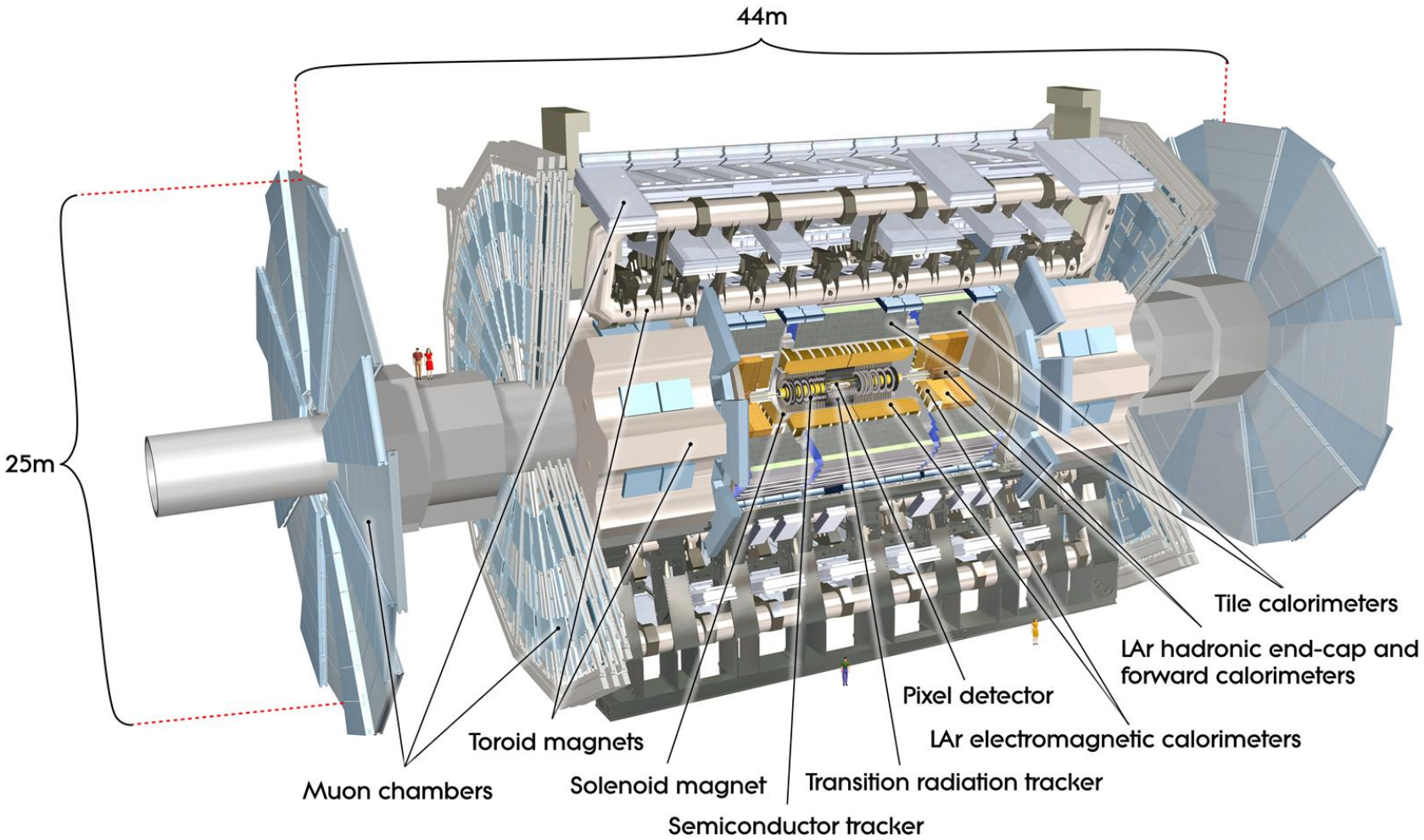
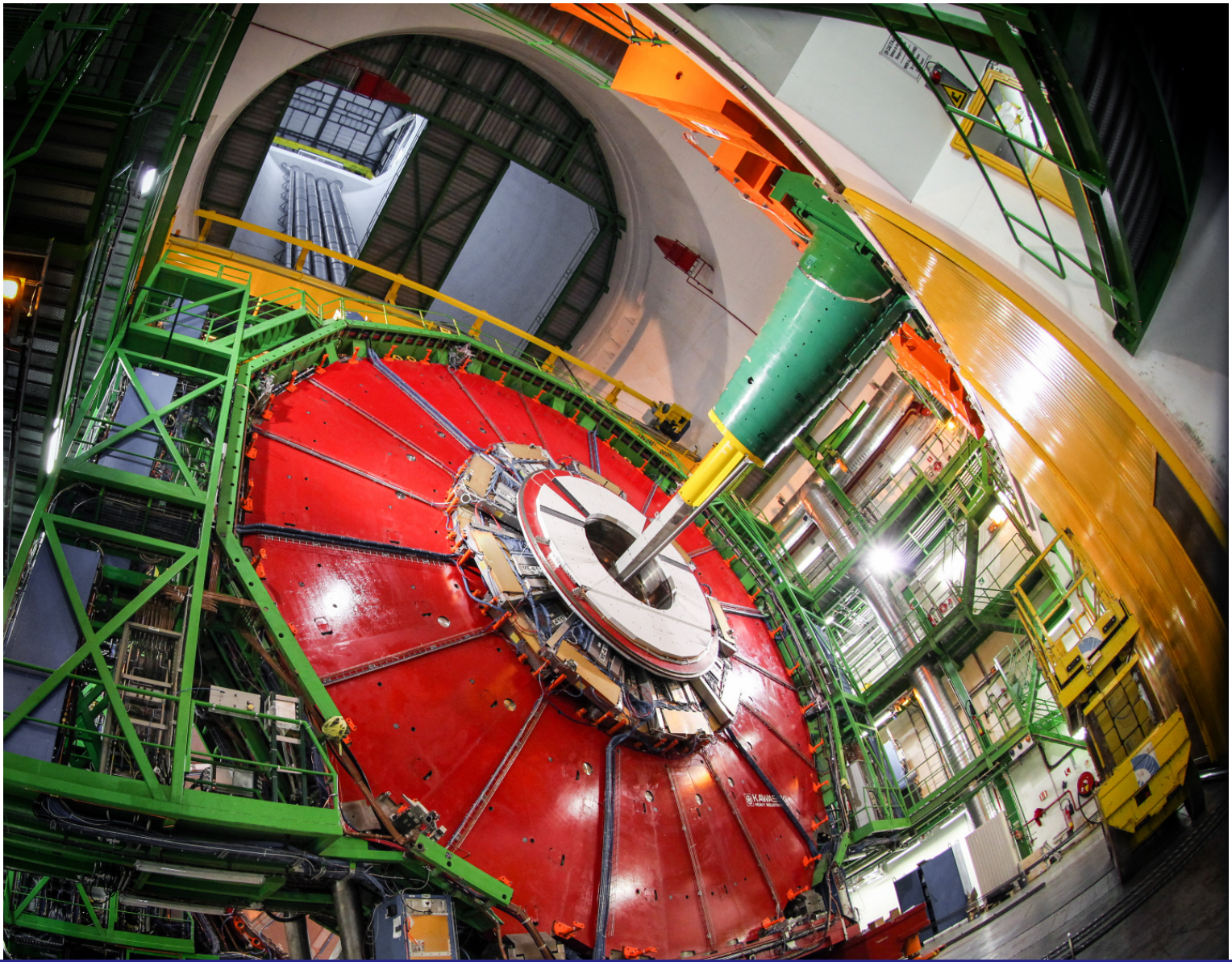
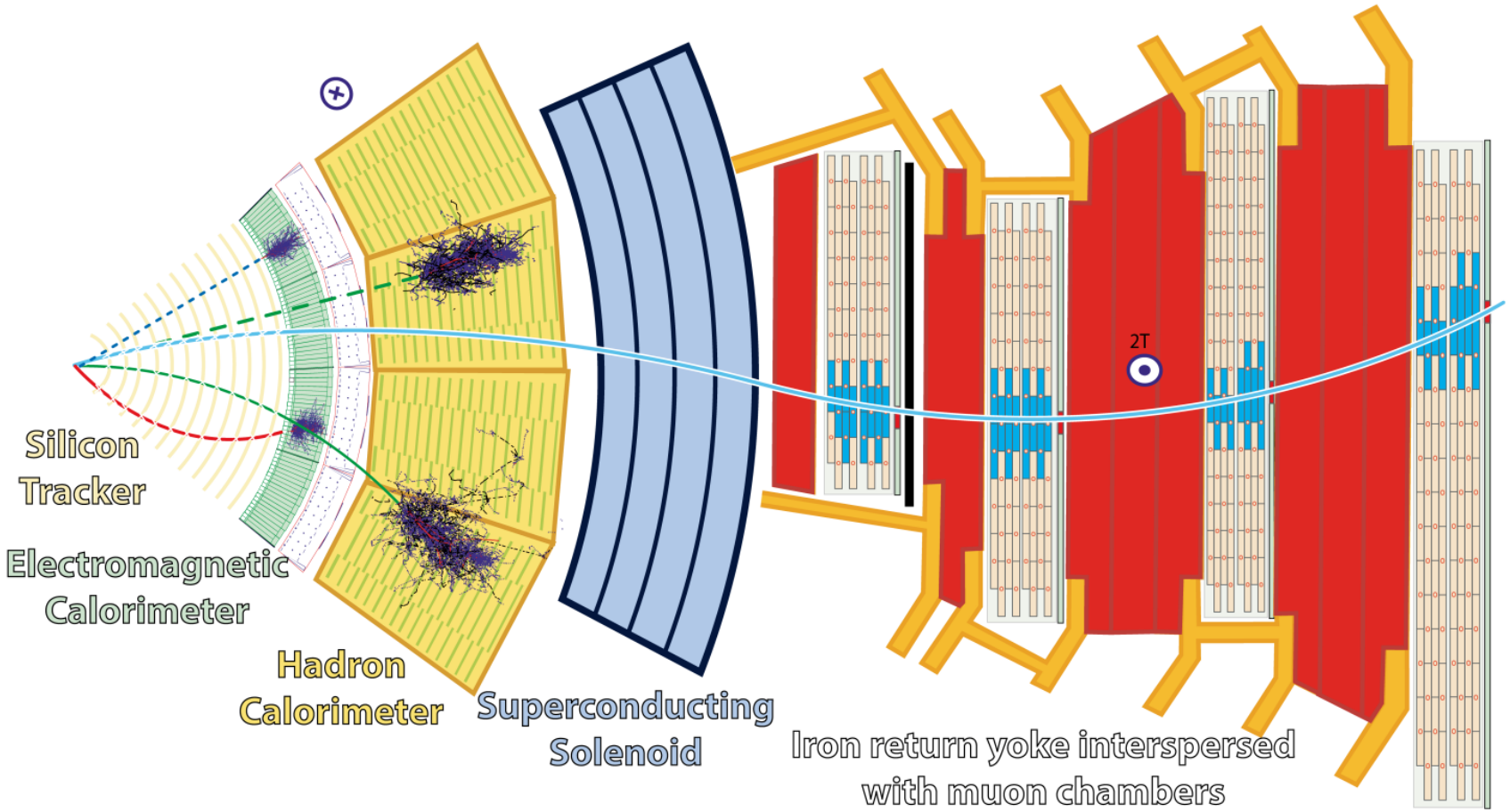

44m
25m
Tile calorimeters
LAr hadronic end-cap and
forward calorimeters
Pixel detector
LAr electromagnetic calorimeters
Toroid magnets
Muon chambers
Solenoid magnet
Transition radiation tracker
Semiconductor tracker

Compact Muon Solenoid (CMS)

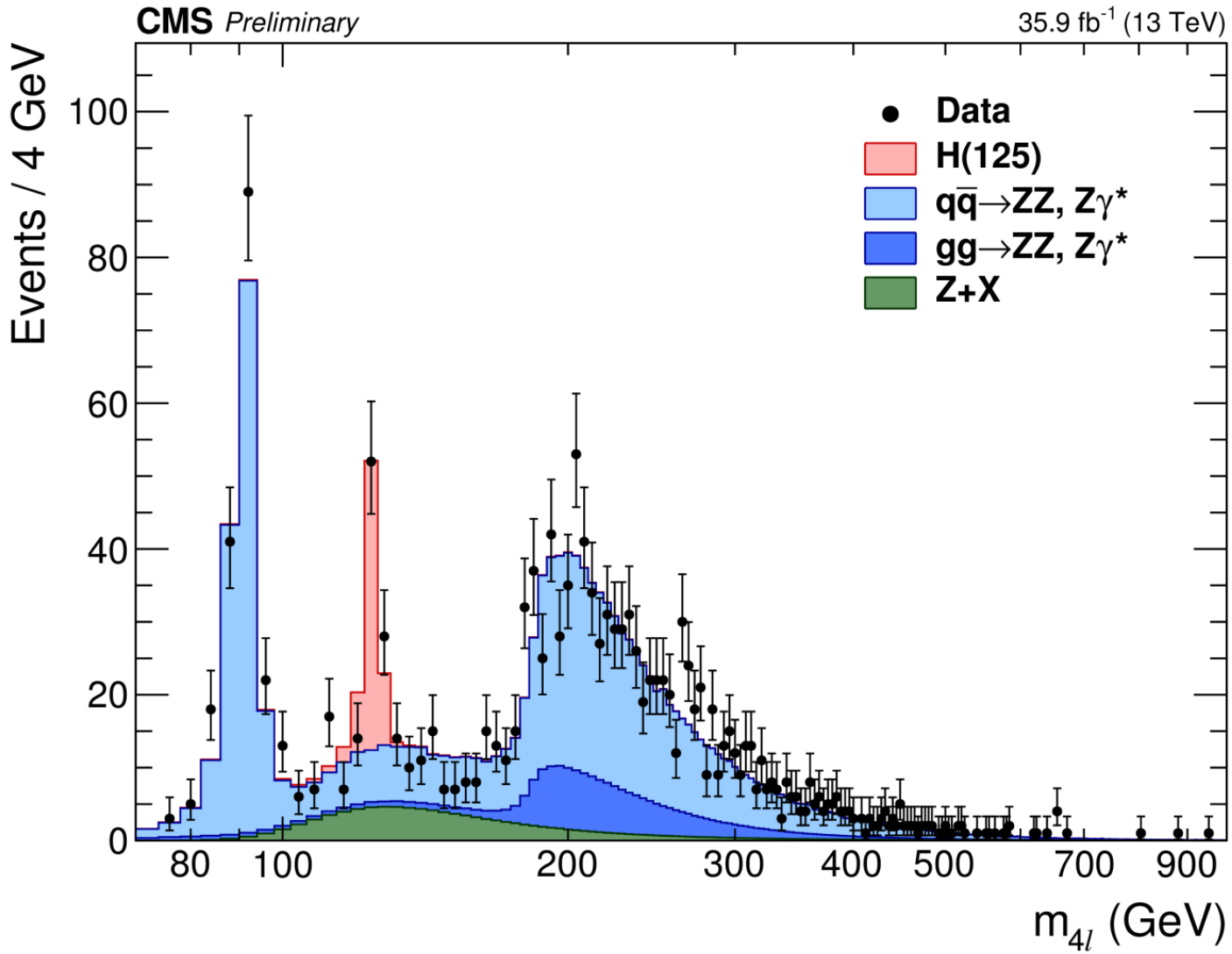


CMS



Muon
Electron
Charged hadron (e.g. pion)
Neutral hadron (e.g. neutron)
Photon

CMS confirmed the higgs, measuring its mass



Collecting knowledge obtained in classical and quantum systems in elementary particle physics, cosmology and also on all other fields of physics — atomic, molecular, solid state, liquids — we are able to better and better understand "nature".

From observations and deep thinking we move more and more towards observations, experiments, mathematics, theories, predictions, ...

General theory of gravity opens a new step in understanding cosmology.

Einstein's equations (which we have almost derived from **Newton's laws in nonrelativistic physics).**

$$(\frac{\frac{dR}{dt}}{R})^2 + \frac{k}{R^2} = \frac{8\pi G\rho}{3} + \frac{5}{3}\Lambda,$$

$$\frac{\frac{d\rho}{dt}}{R} + 3\frac{\frac{d\rho}{dt}}{R}(\rho + p) = 0 \quad .$$

The system is chosen, which is moving with us.
Λ is representing the "dark energy".

"Nature" again surprised us. Besides the ordinary matter and "dark matter" also "dark energy" was observed by measuring of the expansion rate of the universe - Hubble rate.

In elementary particle physics there were hadrons and electrons and neutrinos with the complicated force among hadrons, until the

Standard model of elementary particles and fields was postulated.

It is more than **50 years ago**, when the **standard model** offered an **elegant new step** in **understanding the origin of fermions and bosons** by **postulating**:

- The existence of the **massless family members** with the **charges** in the **fundamental representation of the groups** -
  - the **coloured triplet quarks and colourless leptons**,
  - the **left handed members as the weak charged doublets**,
  - the **right handed weak chargeless members**,
  - the **left handed quarks distinguishing in the hyper charge from the left handed leptons**,
  - **each right handed member having a different hyper charge.**
- The existence of **massless families to each of a family member.**

α name	hand-edness $-4iS^{03}S^{12}$	weak charge τ^{13}	hyper charge Y	colour charge	elm charge Q
u^i_L	-1	$\frac{1}{2}$	$\frac{1}{6}$	colour triplet	$\frac{2}{3}$
d^i_L	-1	$-\frac{1}{2}$	$\frac{1}{6}$	colour triplet	$-\frac{1}{3}$
ν^i_L	-1	$\frac{1}{2}$	$-\frac{1}{2}$	colourless	0
e^i_L	-1	$-\frac{1}{2}$	$-\frac{1}{2}$	colourless	-1
u^i_R	1	weakless	$\frac{2}{3}$	colour triplet	$\frac{2}{3}$
d^i_R	1	weakless	$-\frac{1}{3}$	colour triplet	$-\frac{1}{3}$
ν^i_R	1	weakless	0	colourless	0
e^i_R	1	weakless	-1	colourless	-1

Members of each of the $i = 1, 2, 3$ massless families before the electroweak break. Each family contains the left handed weak charged quarks and the right handed weak chargeless quarks, belonging to the colour triplet $(1/2, 1/(2\sqrt{3}))$, $(-1/2, 1/(2\sqrt{3}))$, $(0, -1/(\sqrt{3}))$.

And the anti-fermions to each family and family member.

- The existence of the **massless vector gauge fields** to the observed **charges** of the **family members**, **carrying charges** in the **adjoint representation of the charge groups**.

Gauge fields before the electroweak break

- **Three massless vector fields, the gauge fields of the three charges.**

name	hand-edness	weak charge	hyper charge	colour charge	elm charge
hyper photon	0	0	0	colourless	0
weak bosons	0	triplet	0	colourless	triplet
gluons	0	0	0	colour octet	0

They all are vectors in $d = (3+1)$, in the adjoint representations with respect to the weak, colour and hyper charges.

- The **existence of a massive scalar field - the higgs**,
  - carrying the weak charge $\pm\frac{1}{2}$ and the hyper charge $\mp\frac{1}{2}$ as it would be in the **fundamental representation of the groups**,
  - gaining at some step **a "nonzero vacuum expectation values"**, breaking the weak and the hyper charge and correspondingly breaking the **mass protection**.
- The **existence** of the **Yukawa couplings**, taking care of
  - the properties of **fermions** and
  - the masses of the **heavy bosons**.

- The **Higgs's field**, **the scalar** in $d = (3+1)$, **a**

name	hand-edness	weak charge	hyper charge	colour charge	elm charge
$0\cdot$ **Higgs**$_u$	0	$\frac{1}{2}$	$\frac{1}{2}$	**colourless**	**1**
$< Higgs_d >$	0	$-\frac{1}{2}$	$\frac{1}{2}$	**colourless**	**0**

name	hand-edness	weak charge	hyper charge	colour charge	elm charge
$< Higgs_u >$	0	$\frac{1}{2}$	$-\frac{1}{2}$	**colourless**	**0**
$0\cdot$ **Higgs**$_d$	0	$-\frac{1}{2}$	$-\frac{1}{2}$	**colourless**	-1

- **Equations of motion were correspondingly postulated.**

- There is the **gravitational field** in **d=(3+1)**.

- **The *standard model* assumptions have been confirmed without offering surprises.**
- **The last unobserved field as a field, the Higgs's scalar, detected in June 2012, was confirmed in March 2013.**
- **The waves of the gravitational field were detected in February 2016 and again 2017.**
- **The *standard model* assumptions have in the literature several explanations, but with many new not explained assumptions.**
- **Is the *spin-charge-family theory*, offering the explanation for all the assumptions of the *standard model*, the next step beyond both *standard models?***

There are namely many phenomena

- **dark matter**,
- **matter-antimatter asymmetry**,
- **dark energy**,
- **observed dimension of space time**,
- **many other phenomena**,

not yet understood.

- **Can my proposed** *spin-charge-family theory* **explain the observed phenomena**?

Obviously it is the time to make a next steps beyond both standard models.

What questions should one ask to be able to find next steps beyond the *standard model* and to understand not yet understood phenomena?

- **o Where do family members originate?**
  o Where do charges of family members originate?
  o Why are the charges of family members so different?
  o Why have the left handed family members so different charges from the right handed ones?
- **o Where do families of family members originate?**
  o How many different families exist?
  o Why do family members – quarks and leptons – manifest so different properties if they all start as massless?

- **o How is the origin of the scalar field (the Higgs's scalar) and the Yukawa couplings connected with the origin of families?**
  o How many scalar fields determine properties of the so far (and others possibly be) **observed fermions and masses of weak bosons?** (The Yukawa couplings certainly speak for the existence of several scalar fields with the properties of Higgs's scalar.)
- **Why is the Higgs's scalar**, or are all **scalar fields**, if there are several, **doublets with respect to the weak and the hyper charge?**
- **Do exist also scalar fields with the colour charge in the fundamental representation and where, if they are, do they manifest?**

My statement:

- **An elegant trustworthy next step must offer answers to several open questions, explaining:**
  - **The origin of the family members and the charges.**
  - **The origin of the families and their properties.**
  - **The origin of the scalar fields and their properties.**
  - **The origin of the vector fields and their properties.**
  - **The origin of the dark matter.**
  - **The origin of the "ordinary" matter-antimatter asymmetry.**

My statement continues:

- **There exist not yet observed families, gauge vector and scalar gauge fields.**
- **Dimension of space is larger than** 4 (very probably infinite).
- **Inventing a next step which covers one of the open questions, might be of a help but can hardly show the right next step in understanding nature.**

I am proposing the spin-charge-family theory, which offers answers to the open questions of both standard models.

In the literature NO explanation for the existence of the families can be found, which would not just assume the family groups.
Several extensions of the standard model are, however, proposed, like:

- **The $SU(3)$ group is assumed to describe – not explain – the existence of three families.**
  Like the Higgs's scalar charges are in the fundamental representations of the groups, also the Yukawas are assumed to emerge from the scalar fields, in the fundamental representation of the $SU(3)$ group.

- **SU(5) and SO(10) grand unified theories are proposed, unifying all the charges.** But the **spin** (the handedness) **is** obviously connected with the (weak and the hyper) charges, what these theories do "by hand" as it does the *standard model*, and the appearance of families is not explained.
- **Supersymmetric theories, assuming the existence of bosons with the charges of quarks and leptons and fermions with the charges of the gauge vector fields, although having several nice properties but not explaining the appearance of families (except again by assuming larger groups), are not, to my understanding, the right next step beyond the *standard model*.**
- **String theories are proposed, which can help a lot to make the theory consistent.**

- **Our workshop "What comes beyond the standard models" is devoted to searching for new ideas and new proposals and answers to the proposals.**

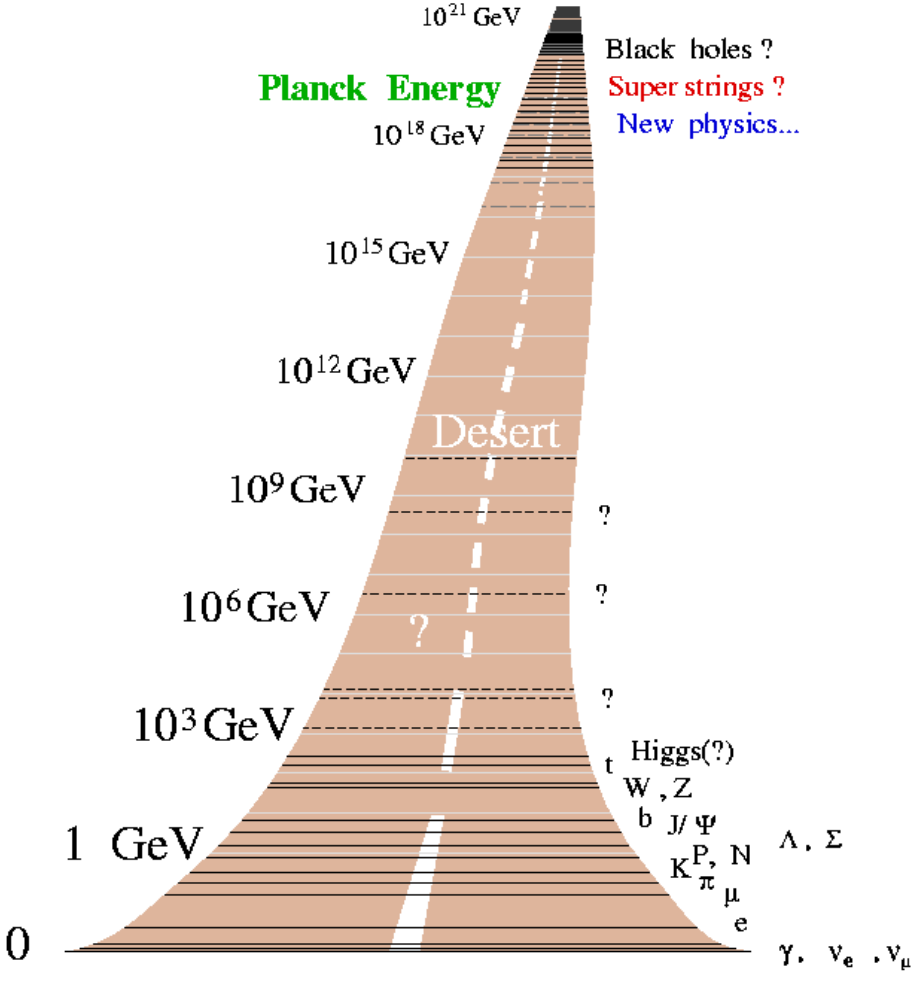
- **In a small group we are discussing openly all our proposals. We have succeeded a lot.**

o The **Spin-Charge-Family** **theory does offer the explanation for all the assumptions of the standard model**, **answering up to now several of the above cited open questions!**

o Not only of the elementary particle fields, but also of cosmology.

o The **more effort** **is put into this theory, the more answers to the open questions in elementary particle physics and cosmology is the theory offering**.

- The **spin-charge-family theory explains**, for example, the **desert to the Planck scale, predicting that there are two groups of four families**, and **several scalar fields, what explains the appearance of** the **dark matter and the existence of more matter than the anti matter in the directly observed part of our universe**.
- The **spin-charge-family theory, can explain**, for example, the **desert to the Planck scale, predicting that there are two groups of four families**.



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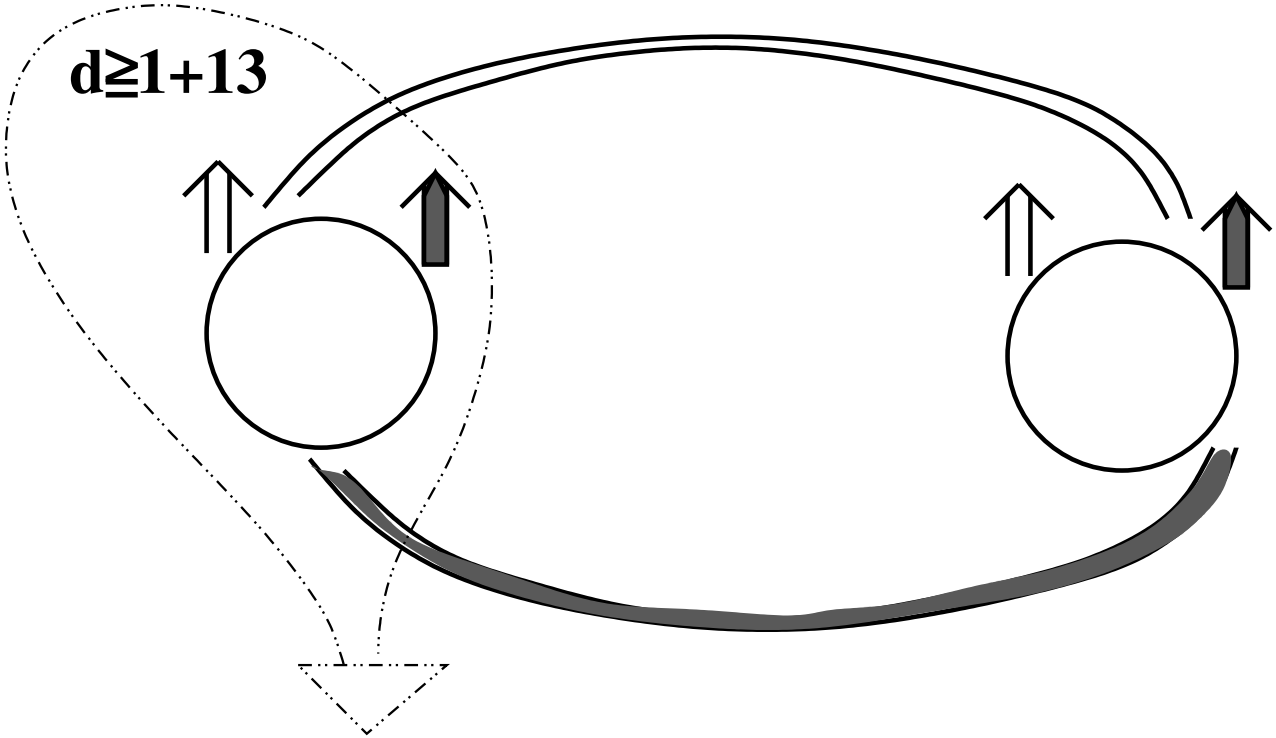
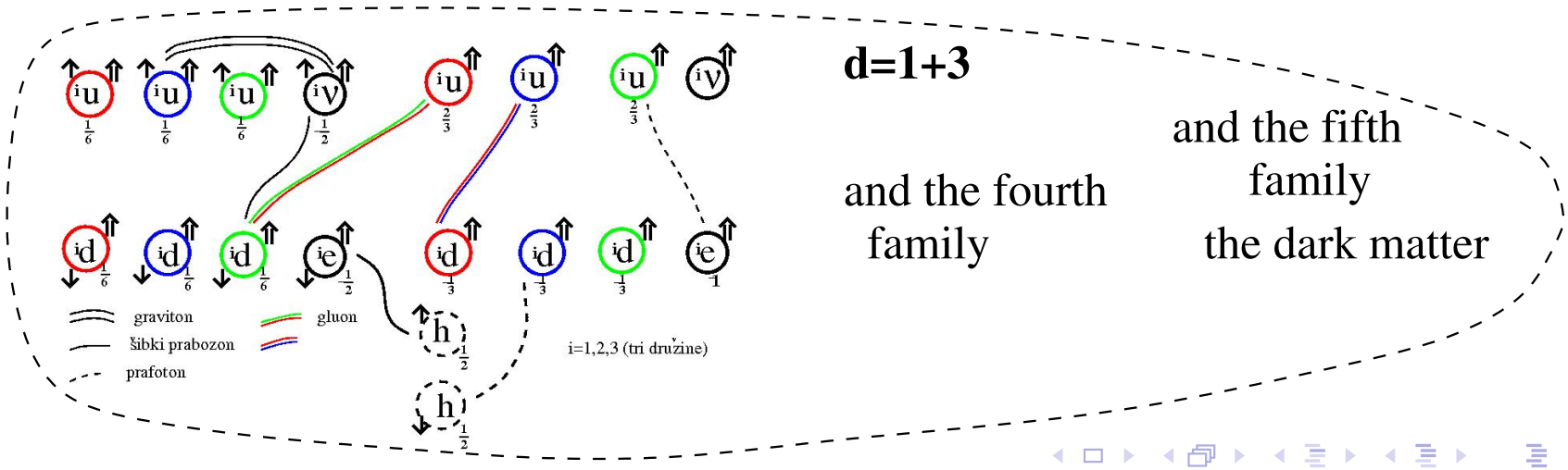
- **After or even before the Planck scale the space can show up ∞ dimensions**.


d≧1+13


graviton
gluon
šibki prabozon
prafoton
i=1,2,3 (tri družine)
d=1+3
and the fourth family
and the fifth family
the dark matter

- **But there are still a lot of questions to be solved**.
- **Correspondingly we must propose elegant simple theories, and observe and make clever experiments, and .....**
- **We understand better and better what are laws of "nature", but yet a lot of open questions remain unanswered.**
- **We understand better and better how the evolution of the life has gone but yet a lot of open questions remained unanswered**.
- We understand better and better how the many body problem, governing the human society works, but yet all the open questions regarding how our civilization and (if at all) is going to survive remain unanswered.

There are several kinds of telescopes used to observe our Universe:

- Telescopes using (detecting) electromagnetic radiation of different wavelenths (energies):
  - Radio waves: kiloHertz $10^3/s$ to several 100 Ghz. Radio antennas. (millimeter waves)
  - light: infrared (10^{-3}m to 10^{-6} m (micro meter), optical (1000 nm to 100 nm, 350 – 700 is light visible to our eyes). Mirrors and lenses.
  - EUV (Exteme UV) several 10 nm to nm, X-rays: specially formed (nested) mirrors
  - X-rays, gamma rays: special telescopes, area detectors
- neutrino telescopes: in very early stages, mostly detection of single (high energy) neutrinos
- cosmic ray telescopes: detection of particles that are produced when cosmic ray particles strike earth's atmosphere nad generate 'showers' of particles
- gravitational wave detectors

Radiotelescopes:

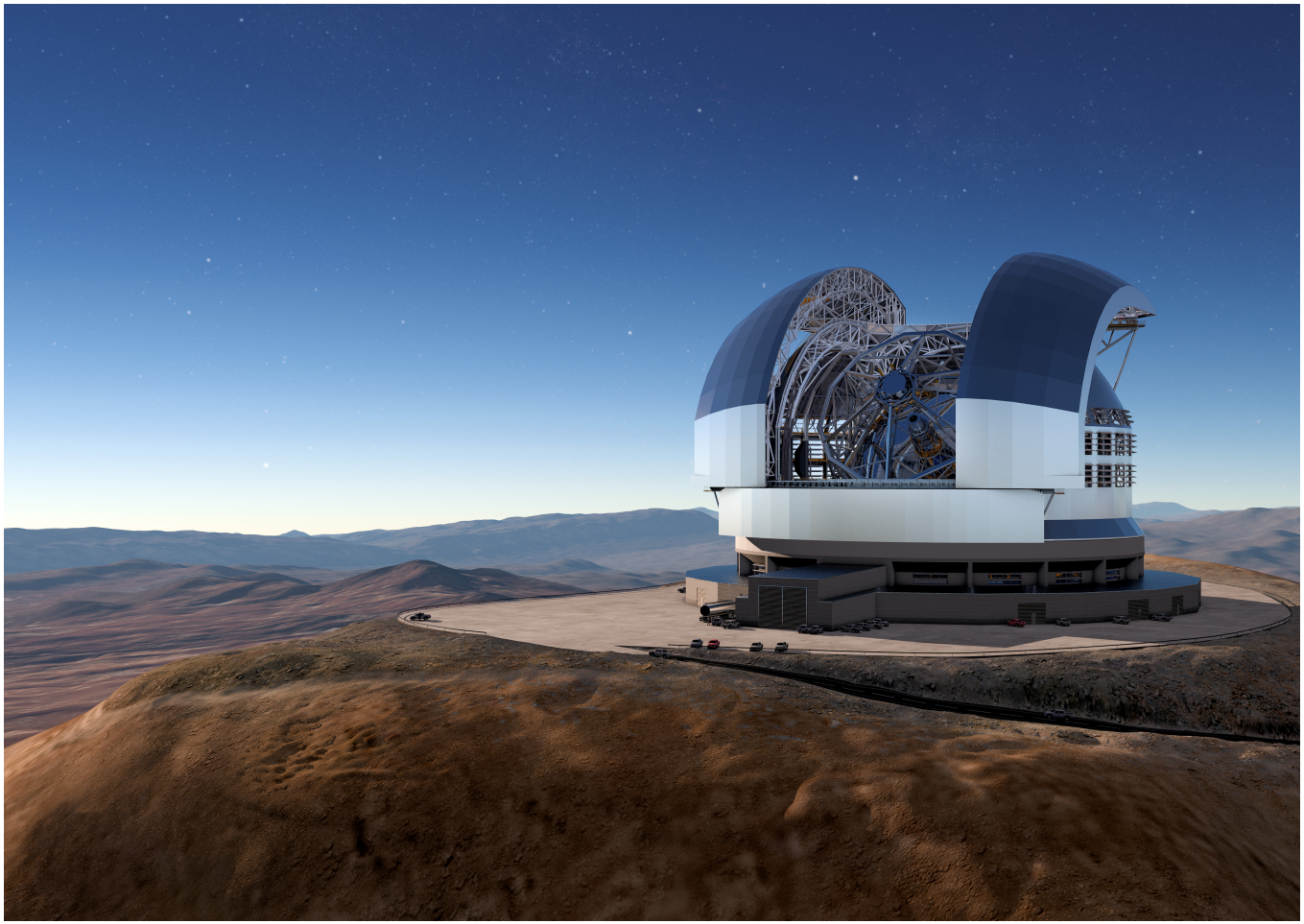
- For longer wavelenths (down to meter) classical antennas (aerials) such as were used for the TV's are used. Many such antennas used together
- for the shorter wavelenths: parabolic dishes are used
  - fixed (large) dishes: 300 m in Arecibo, Puerto Rico; 500 m in China, preparing for operation
  - moveable (single) dishes: up to 100 m
  - Many antennas: often operated together as 'interferometers' to increase resolution. Examples: VLA (very Large Array, New Mexico; ALMA, Chile)

Very Large Array: 28 antennas (27 active, 1 spare), each 25 m. Antennas arranged in 'Y' form. Can be moved on tracks for a maximal effective diameter of about 45 km – larger the size, greater the resolution.

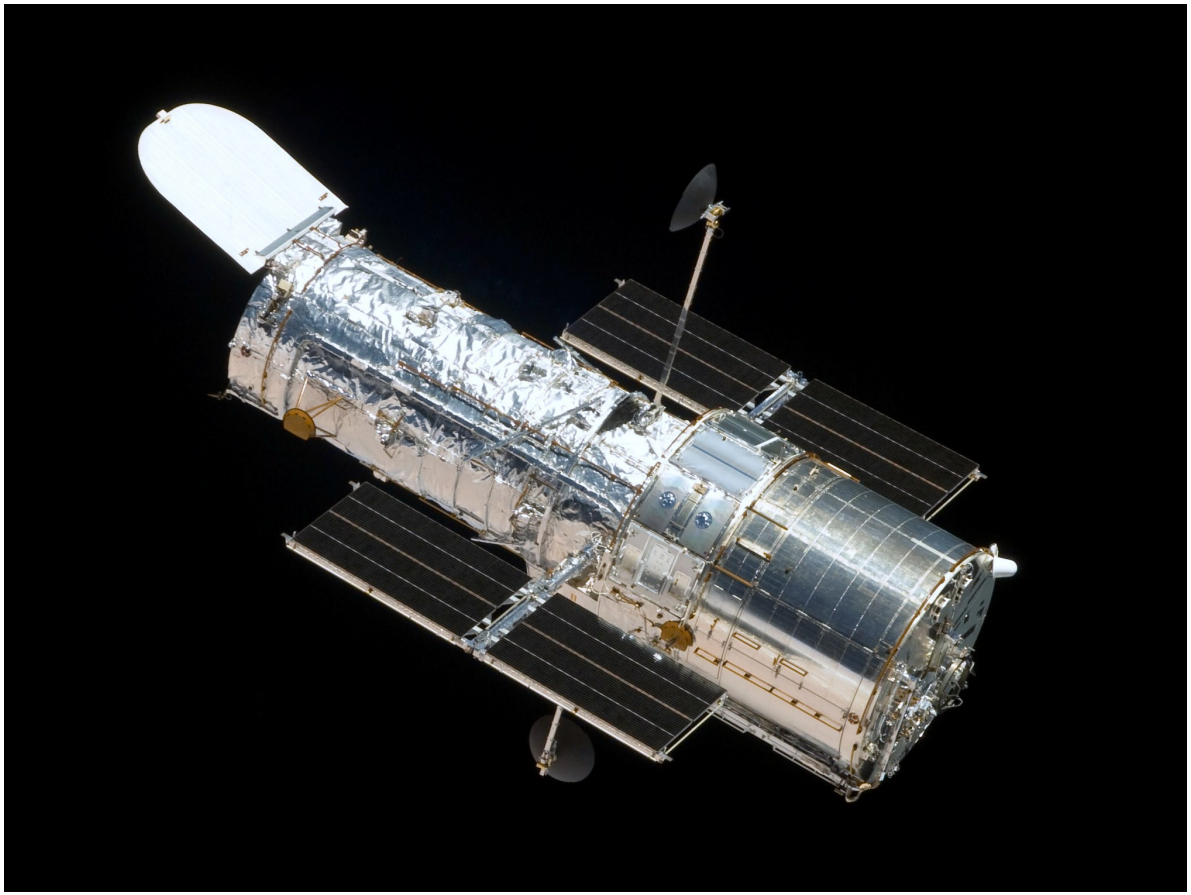
Aray ALMA in Atacama desert in Chile. Is is dedicated to millimeter wave astronomy. It enables to see inside clouds of gas and dust containing young stars or center of our galaxy, which also contains lots of matter (dust and gases) absorbing visible light.

The largest currently in operation optical telescope in VLT (Very Large Telescope) in Paranal, Chile. It is operated by the European Southern Observatory (ESO). VLT consists of 4 telescopes with 8 m mirrors, which can also be combined in a single telescope for observations.

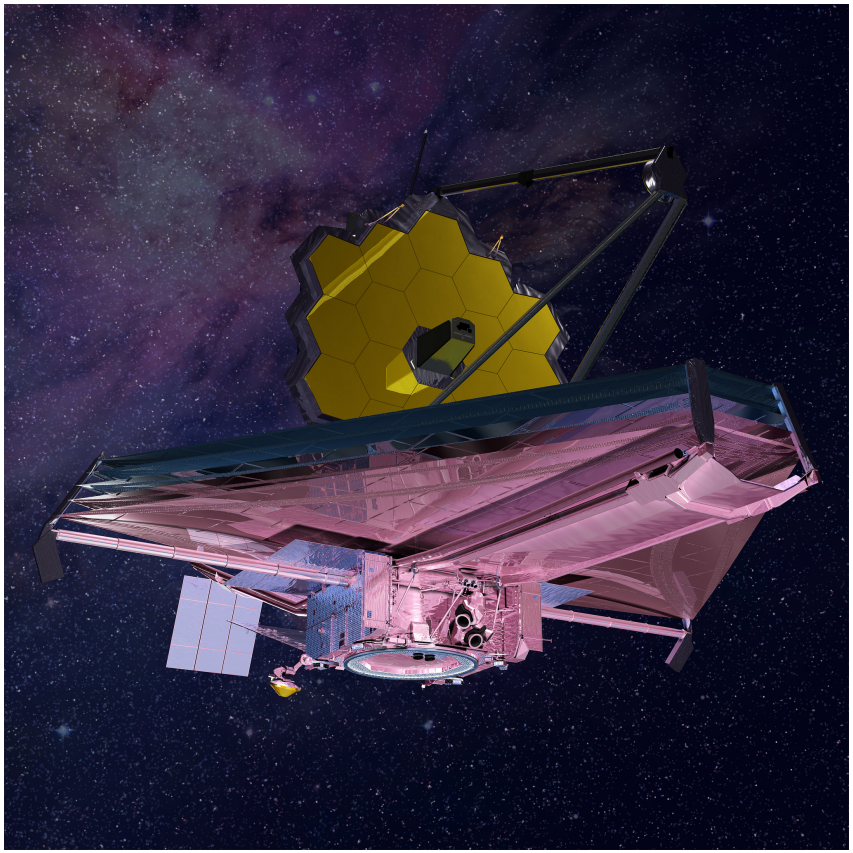
Currently under construction is ELT (Extremelly Large telescope), also by ESO. To begin operation in 2024.
The ELT will gather 100 000 000 times more light than the human eye, 8 000 000 times more than Galileo's telescope, and 26 times more than a single VLT Unit Telescope.



Hubble telescope: in space, so not limited to wavelenths for which our atmosphere is transparent: IR, visual, UV. Almost 30 years in operation.



James Webb Space telescope — 18 hexagonal mirror segments made of gold-coated beryllium that combine to create a mirror with a diameter of 6.5 meters, IR and visual. To be launched in 2021.



Open questions to be answered by Managers: