

Beauty and Physics panel

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John Keats in Ode on a Grecian Urn:

"Beauty is truth, truth beauty," – that is all
Ye know on earth, and all ye need to know.



Proponents of beauty

Henri Poincare: “The Scientist does not study nature because it is useful to do so. He studies it because he takes pleasure in it; and he takes pleasure in it because it is beautiful”

Hermann Weyl: “In my work, I have always tried to unite the true with the beautiful; but when I had to choose one or the other, I usually chose the beautiful”

Murray Gell-Mann: “Beauty is a very successful criterion for selecting the right theory... In 1957 we published a partial theory of weak interactions which disagreed with seven experiments. We believed they were wrong because our theory was beautiful ... and they were”

Paul Dirac: “it is more important to have beauty in one’s equations than to have them fit experiment”

Beauty more important than truth?

Jesus Zamora Bonilla divides scientists and science philosophers into

- 1. Platonists** (ultimate explanation of the Universe must possess beauty, beauty = essential part of research)
- 2. Sceptics** (scientific research has nothing intrinsic to do with beauty)

Sceptics are the most common within the philosophers of science, and within most practicing scientists **outside of quantum physics**

Definition of Beauty

Two criteria suggested by Frank Wilczek:

1. **Productivity**, getting out more than you put in: The more phenomena one can explain with less equations, the more beautiful the theory is.
2. **Symmetry**. According to Wilczek it's change without change. “You can make changes in physical objects or changes in the laws that could change them but don't”.

Functionality, minimalism, simplicity, effectiveness

Beauty as proper conformity of one scale to another

Artistic beauty is different

Ernst Gombrich:

Artistic beauty relies on a tension between symmetry and asymmetry.

Philip Ball: "... for Plato it was precisely art's lack of symmetry (and thus intelligibility) that denied it access to real beauty."

Art: matter of taste
Art: temporary

Science: universal
Science: eternal



Jackson Pollock

Popular beauty is different

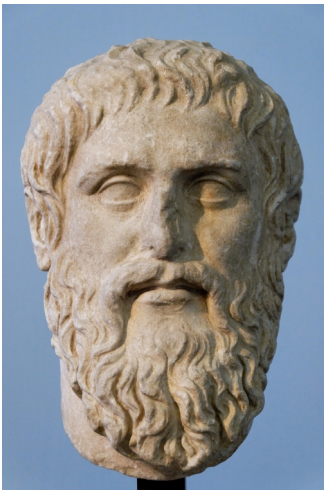
Lay people find mystery beautiful - once explained, it is boring
(you found the Higgs, now what?)

Scientists want to demystify – once they understand, it is beautiful

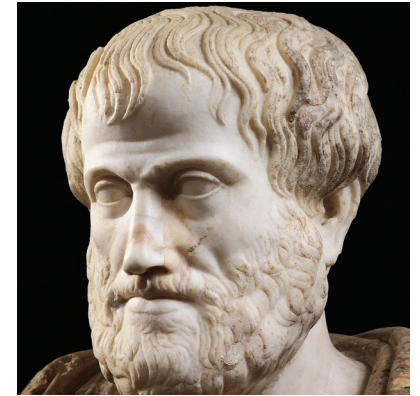
Archeological pit: just a pile of old stones until you understand

Beauty of experimentalists is different?

The measurement process is beautiful by itself without referring to symmetry



Plato vs Aristotle



Aristotle: Nature is as it is, things are as they are
Beauty is artefact of thinking, epistemic tool
materialistic view

Plato: Beauty is Idea more real than things
Matter has to follow laws (and beauty)
Jewish and Roman view

Can beauty misguide us?

1. Kepler's discovery of elliptical orbits was delayed because of his belief in beauty of the circles
2. Weyl: his theory of gravity failed even though he refused to give it up because of its beauty

We should be open-minded

Insistence on perfect symmetry as a bias

Like impressionists' paintings lose their beauty when observed very close, the search for beauty in physics (symmetry and other guiding principles, successful so far above the Planck length) might fail when naively extrapolated down.

We should be ready for unexpected complicated stuff (Plato cannot guarantee us this cannot be so).

Beauty in physics?

A series of beautiful facts (observations, symmetries, conservation rules, invariance principles) neatly sewed together into powerful theoretical and experimental framework resulting in profound understanding of the observable Universe, prediction of new phenomena, and exploitation of established knowledge in benefit of mankind.

Symmetries are so important that even broken ones are vital ... and can be restored

Religious connotations

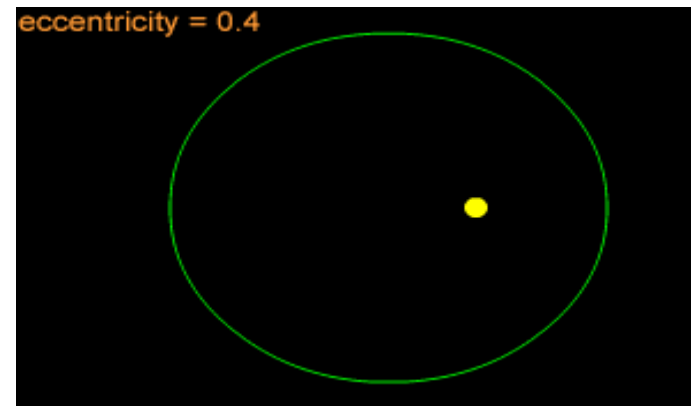
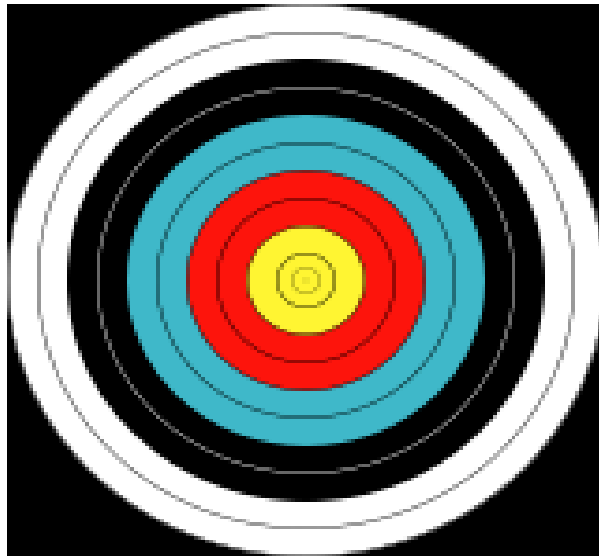
Be careful with theory of everything – it is dangerous, a religious belief

Marcelo Gleiser sees in pursuit of further unification a renewed religious impulse. “ In some sense, physicists have replaced their one true, symmetrically-faced God with one true, symmetric theory”.

Backup slides

Circular symmetry and Newton's theory

Assumption: planetary orbits are circular



Planetary orbits are not circular!

Newton's gravitational law

$$F = G \frac{m_1 m_2}{r^2}$$

Important lesson: symmetry does not apply to the orbits (the solutions of the gravitational law), but to the law itself.

There can be many solutions to the law, some beautiful, some less so, but the law behind is one and it is beautiful.

Lorentz symmetry, special relativity and laws of electricity and magnetism

Einstein built his **special theory of relativity** on a postulate that the laws of physics are the same in the so-called inertial frames of reference (they have Lorentz symmetry).

The **Maxwell's equations of electricity and magnetism** do not change under Lorentz transformations. They also illustrate the first criterion at work: from just four equations one derives all electricity, magnetism and optics.

$$\nabla \cdot \mathbf{E} = 4\pi\rho$$

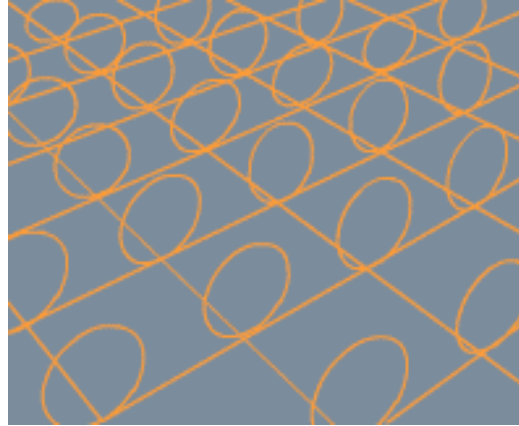
$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{1}{c} \frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \frac{4\pi}{c} \mathbf{J} + \frac{1}{c} \frac{\partial \mathbf{E}}{\partial t}$$



Gauge symmetry and Quantum Electrodynamics



$$\mathcal{L} = \bar{\psi}(i\gamma^\mu D_\mu - m)\psi - \frac{1}{4}F_{\mu\nu}F^{\mu\nu}$$



$$\nabla \cdot \mathbf{E} = 4\pi\rho$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{1}{c} \frac{\partial \mathbf{B}}{\partial t}$$

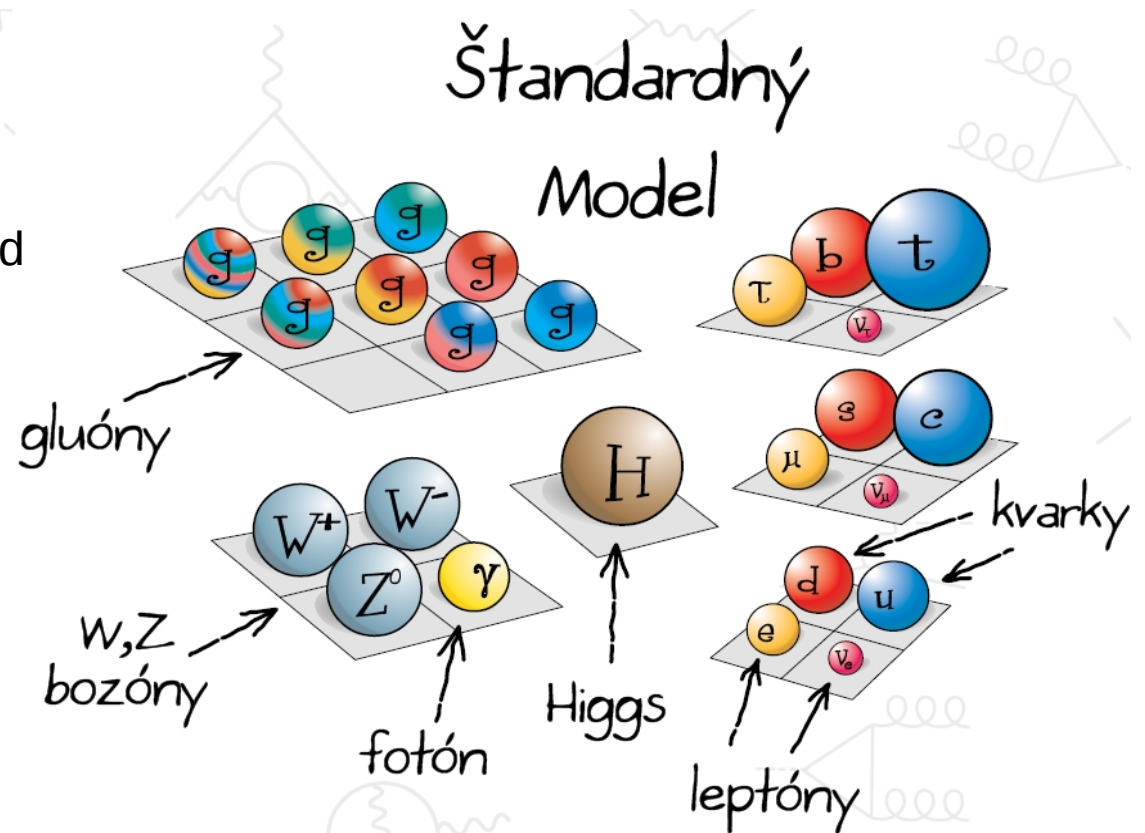
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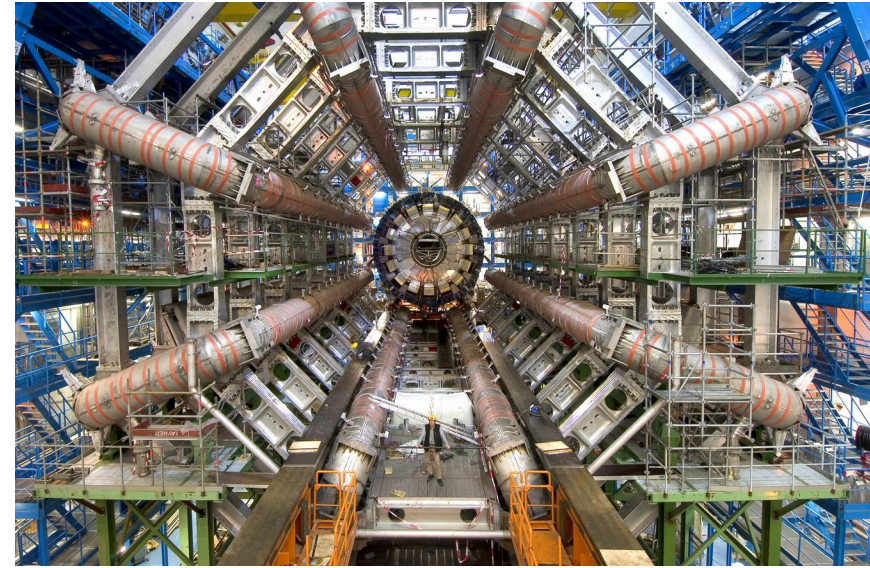
Standard model of particle physics

Gauge theory of strong, weak and electromagnetic interactions

The symmetries are more complicated than the circle symmetry but the gauge principle is there and its beauty is even more profound.



Search for supersymmetry at LHC



The role of beauty as a guide is the role of a good servant of the truth.

The LHC was motivated not only by the Standard model and the Higgs boson but also by new theories such as Supersymmetry.

Supersymmetry was built with aesthetic arguments as its cornerstones.

One mathematical and two physical arguments with a high aesthetic value in favour of supersymmetry.

Supersymmetry, unlike the Standard model, offers a way to unify the three interactions, electromagnetic, weak and strong into a single one and at the same time it provides a good dark matter candidate

Conclusions

Fundamental laws of this world are beautiful (symmetry and productivity)

Physicists realize this and so far seem to confirm Plato's view about existence of perfect beauty in the form of Idea

Artistic beauty seems to be different

Proponents of beauty cont'd

J.W.N. Sullivan: “The measure of the success of a scientific theory is, in fact, a measure of its aesthetic value, since it is a measure of the extent to which it has introduced harmony in what was before chaos”

Heinrich Hertz: “James Clerk Maxwell’s fundamental equations of electricity and magnetism have an independent existence and an intelligence of their own, that they are wiser ... even than their discoverers, that we get more out of them than was originally put into them”

Richard Feynman: “You can recognize truth by its beauty and simplicity. When you get it right, it is obvious that it is right - at least if you have any experience - because usually what happens is that more comes out than goes in”

Frank Wilczek: “My work has been guided by trying to make the laws more beautiful”