

Is there a Theory of Everything and can a layman understand it?

Summary

A Theory of Everything, ToE, is one which aims to unite all laws of nature under one single theory. In particular, it should unite the standard models of particle physics and gravity. The former is a relativistic quantum field theory and describes small-scale phenomena with astonishing accuracy, while the latter is at present Einstein's classical general theory of relativity describing large-scale phenomena. In nature this unification happened in concrete form at the very early moments of the 'big bang' expansion of the Universe.

We now have an impressive amount of experimental information on the Universe as a whole, and this is what a ToE should explain. In cosmology we know the size, age (13.7 Ga) and energy and matter content of the Universe, and in particle physics we have access to 26 measured or soon-to-be measured quantities. There are masses for 12 matter quanta, for example, which vary by 14 orders of magnitude, i.e. by a factor 10^{14} , from the smallest neutrino mass to the greatest quark mass. All these vastly differing figures should be derivable from one single theory, a ToE.

Of course, there still are outstanding questions which are awaiting more experimental facts. What is the dark matter which we know permeates the Universe? Does the Higgs particle, a scalar particle describing excitations of the vacuum, actually exist? We know a lot, but do we perhaps not yet know enough to lead us to a ToE?

One can imagine different types of Theories of Everything. On the first level, we can take it as our goal to explain our Universe and everything we see in it, all the measurement made in cosmological and particle physics up to the present time and in the future. Temporally, the ToE should explain everything from the initial cosmological singularity from which the big bang started into the infinite future. This would be a remarkable undertaking, so vastly different are the scales one is aiming to ex-

plain. One can also imagine a second level of ToEs, however, which explains not only our present Universe but also everything beyond it, everything we can never have had any causal contact with. In fact, since a ToE unites gravity with quantum physics, it is quite natural that there should be not only the one Universe in which we live but also an infinite multitude of other universes. This will be an extension of the paradigm of empirical science, in that we are meaningfully discussing phenomena that we can never verify experimentally.

Clearly, no ToE exists at present, even though some 50 000 scientist years and an intellectual capacity of 10 to 100 Einsteins has been devoted to its search. At present the closest candidate is string theory, a technically very complicated set of equations which unfortunately do not yet exist in a final form. Also, there is no way of deriving experimental consequences even from the present equations.

The goal of a ToE is a grand one. One might say that it strives to explain scientifically what religion is doing by way of beliefs. At this stage one must remember that a ToE as such could only set the stage for explaining how life and consciousness have emerged, another grand-scale problem. An enlightened layman might be worried about understanding it. Clearly nobody can understand all the technical details, nor needs to do so. What one needs is firstly number sense, having a feeling for physical quantities that varying by extremely many orders of magnitude. Secondly, one should have a feeling for what special relativity means (light velocity is the maximal velocity, which can only be attained by massless particles) and for how quantum physics limits our classical intuition of motion (the position and momentum of a particle fluctuate so that their product is larger than Planck's constant).

In conclusion, it is quite likely that a ToE in the sense of explaining everything we see in our present Universe does exist, but it is still very far away, and we may need a great deals of new experimental information to help us progress towards such a goal. And if this theory is discovered, it will have to be understandable for a layman in the general sense outlined above, otherwise it will be no good as a ToE!