TOE-tology

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Feb 27, 2010

Modern physics is currently going through a major soul-searching phase. This is evident from the large number of popular science books that have appeared over the last couple of decades, starting with Stephen Hawking's "Brief History of Time". However, since that memorable volume, the tone of most books has become split between the enthusiastic and the critical (sometimes even bordering on the cynical). The authors of the second category tend to refer to the first category as hype, while the authors of the first category do their best to ignore the second category.

Among the enthusiastic volumes can be found books such as Brian Greene's "Elegant Universe", and Luther Lews Jr.'s "Our Superstring Universe". Among the critical volumes can be found books such as Peter Woit's "Not Even Wrong", Lee Smolin's "The Trouble With Physics", or Robert B. Laughlin's "A Different Universe". Not all works fit in these categories, of course, there being no better example than Roger Penrose's various controversial but fascinating contributions.

However, even without going as far as to label the enthusiastic contributions "hype", it is clear that modern physics is going through a period of uncertainty. No major advances have been made for almost three decades. Gravity and quantum fields remain as incompatible as they have always been.

Most scientists agree that this stagnation is a classic symptom of looking at the problem the wrong way. Most scientists also agree that some fresh new approach is needed.

In this essay, I would like to point out that the notion of tautology, though not much more than a term of abuse and/or insult (i.e. a "four letter word") in modern scientific discourse, deserves much closer and more serious scrutiny. Tautology needs to be taken seriously. Here is why.

The scientific and popular-scientific literature often refers to two different notions as if they were the same: unification and the "Theory of Everything". In other words, it is assumed that unification of gravity with the forces of the Standard Model (quantum fields) would lead to a Theory of Everything.

Here, I would like to point out that one aspect is being overlooked: ***unifying gravity and quantum fields in a way compatible with experiment is necessary, but not sufficient, to obtain a TOE.***

Suppose we have a number of unification theories to choose from, numbered from 1 to N. Suppose an experiment or series of experiments was put forward, which would be able to incontrovertibly distinguish between them, to the benefit of one of them. In that case we would have a theory X, $1 \leq X \leq N$, which is the only one that has passed the test of experiment, and thus, since it would unite gravity and quantum fields, it would be the only candidate to a Theory Of Everything, or TOE.

But since it is amenable to experimental test, that means it has some content, it is a formalism, based on some fundamental concept or set of concepts α', which corresponds to some experimental object or set of objects α. In other words, there is some imaginable other way that things could have been, and experiment has forced us to choose *this*, the X version, corresponding to the existence of α. The latter could correspond, for instance, to the values of a series of free parameters, which may only be determined by experiment.

However, if this was the case, then that means that X could never truly be a TOE because one could always ask questions such as "Why does our universe contain α ?" "Who decided that ?" or “What is α made of?”

X could never answer such a question, because, obviously, an experiment was needed to pick it out

of the list of available theories, hence that question was only answerable by experiment. The only possible answer to those two questions would be "Experiment decided". The fact that experiment was needed, implies automatically that the theory is not complete.

Hence X could never truly be a TOE.

To put it shortly, a TOE would have to be such that it could not possibly be wrong, and the only thing that cannot possibly be wrong is a tautology. Another consequence is that such a theory would also be untestable.

The conclusion is impossible to escape: ***a true TOE, if it exists, must be untestable, i.e. a tautology, or a TOE-tology.***

This is a fact with potentially deep ramifications.

In science, tautology is a four letter word. It is one of the most effective ways to discredit an idea or approach, on the grounds that it "has no content". However, I believe that this is purely a Western cultural artifact, a result of the way science developed historically, and of the philosophical and religious framework surrounding its development.

An example may shed some light on what I mean.

The Pythagorean theorem is a consequence of the axioms of Euclidean geometry. In fact, it can be shown to be equivalent to the famous "parallel postulate". Hence, the Pythagorean theorem and the parallel postulate are two ways of saying the same thing. The statement "In Euclidean geometry the Pythagorean theorem holds" is an untestable truth, a tautology (since the theorem is already contained in Euclid's axioms from the start), yet, it has never been criticized on those grounds, and its usefulness and importance has never been in doubt.

The usefulness stems from the ***relationship*** it implies, between two different concepts. The statement is purely relational, it does not imply the "existence" or "reality" of something, but a relationship between two things whose “existence” is irrelevant, and, indeed, meaningless. The only thing that has any reality, in this context, is the relationship itself. It is also not testable, because things cannot possibly be any other way, and yet, it is far from lacking content or usefulness. Logically, there is no distinction between the axioms and the theorem, but operationally there is a difference: by using the theorem instead of the axioms ***we save time***. The theorem has ***computational content*** which the axioms lack.

The standard counter-argument is that Euclidean geometry is mathematics, but that in actual empirical science things are different because they deal with actual objects, not with "fictitious" conceptual objects. So science needs to do more than mathematics, it needs to do more than just find relationships. In addition to characterizing relationships between objects, science needs to know what objects "are" and what they are "made of".

However, this view is false. In empirical science existence (through which questions related to what something "is", or is "made of", acquire any meaning at all) is meaningful only within the framework of observation. Something exists to the extent that it is observed. The best empirical science can do, therefore, is to characterize observations, i.e., interactions, or relations between objects, where one object is arbitrarily designated as "observer" and another is arbitrarily designated as "observed". Thus, ***empirical science is no less relational an enterprise than mathematics itself.***

So, even though tautology does not seem to bother anyone in mathematics, it is only for historical reasons that it has remained beyond the pale in empirical science.

I should point out that there is a movement which is gathering considerable momentum, and which has begun to try smuggling this approach into empirical science. It is known as "emergence".

Emergence focuses on how phenomena come about through the interaction and complex relationships among other phenomena. In this sense, the higher level, or "emergent", phenomena, are seen *both* as qualitatively different from their constituent parts, *and* as essentially equivalent to the sum of their parts. The difference resides, in sense, in *how the parts are summed*; in effect the parts themselves are not important to the higher level phenomenon, but only the *pattern* of their interactions. This view finds its most concise formulation in P.W. Anderson's Science Magazine® article: "More is different". For instance, the Pythagorean theorem may be seen as an emergent phenomenon resulting from Euclid's axioms, plus a certain amount of "interaction" among them, or information processing, i.e., the proof, obtainable in finite time by a Turing machine. The meaning of each individual axiom is irrelevant, what matters is only how they relate. The emergent viewpoint focuses on the ***computational content*** of physical phenomena.

The most radical version of the emergent viewpoint is the one which hypothesizes that not just some, but ***all*** phenomena are emergent, and is most lucidly, eloquently and entertainingly presented in Robert B. Laughlin's "A different universe". In light of the above discussion, this radical viewpoint can be seen to be equivalent to the statement "A Theory of Everything exists," in the sense of this essay. The existence of a TOE is possible only in a relational, computational universe, where only process matters, and where the existence of "objects" (however fundamental) is irrelevant and, indeed, meaningless.

Of course this radical viewpoint begs the question: if every phenomenon emerges from the interactions of other phenomena, does that not lead to an infinite regress, of smaller and smaller phenomena? The answer given is one of the following: 1. Probably not. 2. We will cross that bridge when we come to it. First, there is a strong argument against the existence of anything infinite (be it a regress) on the grounds that nothing infinite has ever been observed (nor theoretically required to explain experiments), and neither is it clear what form such an observation would take. Second, the fact that we don't yet know either whether or how the regress may terminate only means we need to think ***more*** about it, rather than less. The whole idea is only a hypothesis for the time being, but so is every other idea. It obviously needs to be taken seriously first, before it goes anywhere.

To summarize, I have argued that unification is not sufficient for a TOE, that a true TOE, if it exists, must be untestable, that tautology in the mathematical sense is closely related to the emergent approach to science, and that the radical emergent approach is equivalent to the statement that a TOE exists.