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Some thoughts on the future of unified models

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Abstract
I share some thoughts on the future of unified models.

I shall never forget Kurt Goedel, a living legend. I was always intrigued by his theorem. When I was still a young student at the local university in my home town in Turin one of my professors handed me a copy of the Principia Mathematica of Russel and Whitehead, better known to experts under the nickname of ‘diplococus’. Years later I learned that Goedel’s theorem had destroyed the dream of the diplococus.

I am not an expert in logic and I cannot enter into the details of Goedel’s work but some essential points deserve attention also outside the proper domain of mathematics.

Goedel’s theorem states that any non-trivial formalism based on axioms contains propositions which are undecidable, i.e. have no answer within the formalism. Any such proposition is in fact a candidate for a new axiom to be added to the others; it is enough to decide whether it is true or false. The new axiom extends the previous formal language but then this extension will produce in turn more undecidable propositions and add more axioms: the procedure has no end. In the jargon of experts, assigning a truth value to a proposition is called ‘consulting an oracle’. The very idea of consulting an oracle always attracted me.

The language of physical laws is mathematics and Goedel’s theorem must have some relevance to physics and to the real world or rather to the way mankind sees the real word. Goedel’s theorem dealt with number theory while physical laws deal with continuous functions and Hilbert spaces, topics apparently far removed from arithmetics. The history of physics may however suggest some connection. I think that the uncertainty in physical measurement plays in physics the role of the undecidable propositions and that experiments and measurements play that of the oracle.

About two centuries ago a very conservative French abbey, well known as Auguste Cauchy, had an argument with king Louis Philippe and fled to Turin, my home town. In Turin he got a chair at the local university where he completed his celebrated theorem on complex variables. When he left the same chair was given to Amedeo Avogadro.

In 1811, Avogadro published a celebrated article in *Journal de physique* that clearly drew the distinction between molecules and atoms. He pointed out that Dalton had misunderstood the concepts of atoms and molecules. The ‘atoms’ of nitrogen and oxygen are in reality ‘molecules’ containing two atoms each. Thus two molecules of hydrogen can combine with one molecule of oxygen to produce two molecules of water. Avogadro stated in his principle that 'equal volumes of all gases at the same temperature and pressure contain the same number of molecules'.

The principle provided a clear definition of atomic weights which allowed Cannizzaro to derive a first list of weights and to present it at a chemistry meeting in Frankfurt in 1861. The list was eventually extended and got into the hands of Mendeleyev, who then produced the periodic system.

The periodic system was the introduction of atoms, the first elementary particles. It was a triumph which soon began to show interesting flaws. In spite of the name it was not exactly periodic, it had rare earths. Years later Niels Bohr came out with his atomic model and the flaws turned out to be essential in our understanding of the atomic structure at a deeper level.

Atoms ceased to be elementary particles and were replaced by a new list of particles which included electrons and nucleons and then pions, and kept on growing with the energy of accelerators. By the end of the 1930s the list was just as perplexing in number and in mysterious flaws as the old periodic system.

We now have a standard model of elementary particles which includes three or perhaps more generations of quarks and leptons and describes the real world up to energies which are billions of times higher than the chemical ones of the time of Mendeleyev. The model works very well but is by no means symmetric, in fact it strongly reminds me of the flaws of the early models.

A proposal by Harari stated that quarks are no longer elementary and are composed of new entities called preons. I am not an expert on this matter but I am ready to bet that preons or later models, if successful, will show interesting and totally unexpected flaws hinting at a even deeper level. I conjecture that in fact there is no ultimate level, experiments play the role of Goedel's oracle and the show will continue forever and stop only when sadly governments will stop funding research.

The descent into the infinitely small and the behaviour of matter in extreme conditions is absolutely relevant to our understanding of cosmology and of the big bang.

Each step down has opened the door to a scientific revolution. Bohr's model has opened the way to quantum mechanics and quarks are themselves very queer particles, they cannot be the ultimate answer.

An infinite sequence of models of elementary particles means that the history of the universe up to the big bang will contain an infinity of eras. The flow of events should not be measured in billions of years but rather by the succession of eras, and there is no final theory. The big bang is logically infinitely remote in the past. I do not find this infinity distressing, it is a guarantee that the show will never end and that in the centuries to come, if funding permits, there will be always something new, unexpected and I hope exciting.

Infinity also enters the structure at large of the cosmos. The current cosmological model of the universe is based on the theory of general relativity. When it was first conceived by Einstein the universe appeared as a 3-sphere of constant positive curvature and finite volume which kept on expanding. It appears now that the universe is spatially flat and is probably infinitely extended. Of this universe we see only a tiny expanding fragment which keeps on growing at an alarming slow rate. We have no idea of what lies beyond a few dozen billion light years away from earth, but I would be very disappointed if it turned out to be a boring variation on what we already see from earth. If the universe is infinitely extended then any object in agreement with physical laws and no matter how improbable, insolent or just boring will eventually exist somewhere in the cosmos. If we could gaze into infinity and have billions of centuries to waste we would eventually see a giant 300 m tall statue of Woody Allen in aluminium–neodimium alloy and painted blue. Why not?