Editorial

We Need to Find the Theory of Everything

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Abstract

In last week New Scientist has run a short interview with Lisa Randall who told us that we shouldn't be obsessed with finding a theory of everything. It is certainly true that there is a lot more to physics than this goal, but it is an important one and I think more effort should be made to get the right people together to solve this problem now. So here are the answers I would give to the questions asked of Lisa Randall which also touch on the recent discovery of the Higgs(-very-like) Boson.

Key Words: Theory of Everything, Higgs Boson, New Scientist, Lisa Randall.

Each week the New Scientist runs a one minute interview with a scientist and last week it was Lisa Randall who told us that we shouldn't be obsessed with finding a theory of everything. It is certainly true that there is a lot more to physics than this goal, but it is an important one and I think more effort should be made to get the right people together to solve this problem now. It is highly unlikely that NS will ever feature me in their column but there is nothing to stop me answering questions put to others so here are the answers I would give to the questions asked of Lisa Randall which also touch on the recent discovery of the Higgs(-very-like) Boson.

Doesn't every physicist dream of one neat theory of everything?

Most physicists work on completely different things but ever since Einstein's attempts at a unified field theory (and probably well before) many physicists at the leading edge of theoretical physics have indeed had this dream. In recent years scientific goals have been dictated more by funding agencies who want realistic proposals for projects. They have also noticed that all previous hopes that we were close to a final theory have been dashed by further discoveries that were not foreseen at the time. So physicists have drifted away from such lofty dreams.

So is a theory of everything a myth?

No. Although the so-called final theory won't explain everything in physics it is still the most important milestone we have to reach. Yes it is a challenging journey and we don't know how far away it is but it could be just round the corner. We must always try to keep moving in the right direction. Finding it is crucial to making observable predictions based on quantum aspects of gravity. Instead people are trying to do quantum gravity phenomenology based on very incomplete theories and it is just not working out.

But isn't beautiful mathematics supposed to lead us to the truth?

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Beauty and simplicity have played their part in the work of individual physicists such as Einstein and Dirac but what really counts in consistency. By that I mean consistency with experiment and mathematical self-consistency. Gauge theories were used in the standard model, not really because they embody the beauty of symmetry, but because gauge theories are the only renormalisable theories for vector bosons that were seen to exist. It was only when the standard model was shown to be renormalisable that it becomes popular and replaced other approaches. Only renormalisable theories in particle physics can lead to finite calculations that predict the outcome of experiments, but there are still many renormalisable theories and only consistency with experiment can complete the picture. Consistency is also the guide that takes us into theories beyond the standard model such as string theory that is needed for quantum gravity to be consistent at the perturbative level and the holographic principle that is needed for a consistent theory of black hole thermodynamics.

Is it a problem, then, that our best theories of particle physics and cosmology are so messy?
Relatively speaking they are not messy at all. A few short equations are enough to account for almost everything we can observe over an enormous range of scales from particle physics to cosmology. The driving force now is the need to combine gravity and other forces in a form that is consistent non-perturbatively and to explain the few observational facts that the standard models don't account for such as dark matter and inflation. This may lead to a final theory that is more unified but some aspects of physics may be determined by historical events not determined by the final theory, in which case particle physics could always be just as messy and complicated as biology. Even aside from those aspects, the final theory itself is unlikely to be simple in the sense that you could describe it fully to a non-expert.

Did the discovery of the Higgs boson – the "missing ingredient" of particle physics – take you by surprise last July?
We knew that it would be discovered or ruled out by the end of 2012 in the worst case. In the end it was found a little sooner. This was partly because it was not quite at the hardest place to find on the mass range which would have been around 118 GeV. Another factor was that the diphoton excess was about 70% bigger than expected. If it had been as predicted they would have required three times as much data to get it from the diphoton excess but the ZZ channel would have helped. This over-excess could be just the luck of the statistics or due to theoretical underestimates, but it could also be a sign of new physics beyond the standard model. Another factor that helped them push towards the finish line in June was that it became clear that a CMS+ATLAS combination was going to be sufficient for discovery. If they could not reach the 5-sigma goal for at least one of the individual experiments then they would have to face the embarrassment of an unofficial discovery announced on this blog and elsewhere. This drove them to use the harder multivariate analysis methods and include everything that bolstered the diphoton channel so that in the end they both got the discovery in July and not a few weeks later when an official combination could have been prepared.

Are you worried that the Higgs is the only discovery so far at the LHC?
It is a pity that nothing else has been found so far because the discovery of any new particles beyond the standard model would immediately lead to a new blast of theoretical work that could take us up to the next scale. If nothing else is found at the LHC after all its future upgrades it

could be the end of accelerator driven physics until they invent a way of reaching much higher energies. However, negative results are not completely null. They have already ruled out whole classes of theories that could have been correct and even if there is nothing else to be seen at the electroweak scale it will force us to some surprising conclusions. It could mean that physics is fine tuned at the electroweak scale just as it is at the atomic scale. This would not be a popular outcome but you can't argue with experiment and accepting it would enable us to move forward. Further discoveries would have to come from cosmology where inflation and dark matter remain unexplained. If accelerators have had their day then other experiments that look to the skies will take over and physics will still progress, just not quite as fast as we had hoped.

What would an extra dimension look like?
They would show up as the existence of heavy particles that are otherwise similar to known particles, plus perhaps even black holes and massive gravitons at the LHC. But the theory of large extra dimensions was always an outsider with just a few supporters. Theories with extra dimensions such as string theory probably only show these features at much higher energy scales that are inaccessible to any collider.

What if we don't see one? Some argue that seeing nothing else at the LHC would be best, as it would motivate new ideas.
I think you are making that up. I never heard anyone say that finding nothing beyond the Higgs would be the best result. I did hear some people say that finding no Higgs would be the best result because it would have been so unexpected and would have forced us to find the alternative correct theory that would have been there. The truth of course is that this was a completely hypothetical situation. The reason we did not have a good alternative theory to the Higgs mechanism is because there isn't one and the Higgs boson is in fact the correct answer.

References

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