Essay

Return of String Theory to Symmetry & SUSY 2012

Philip E. Gibbs*

Abstract

We know string theory only as a small set of perturbative formulations linked together by non-perturbative dualities. There has to be an underlying theory based on some unifying principle. For about 16 years it has been known that an important element of quantum gravity is the holographic principle. If it is right there must be a huge amount of redundancy in this volumetric description of field theory. Redundancy can be taken to imply symmetry. In this essay, I discuss the importance of symmetry and the return of string theory to symmetry. Separately, The SUSY 2012 conference started in Beijing on August 13, 2012. It is the biggest supersymmetry conference of the year and we expect to see the latest results using the 5/fb gathered in 2012 at 8 TeV before the last technical stop. The most promising anomaly at this time is the 1.8 times SM excess in the diphoton channel seen in the Higgs search which currently has 2.5 sigma significance BSM in ATLAS and 1.5 sigma in CMS.

Key Words: string theory, symmetry, SUSY 2012, diphoton channel, excess, ATLAS, CMS.

String Theory returns to symmetry

The strings 2012 conference has finished and it is great to see that all the talks are online as slides and videos. Despite what you hear from some quarters, string theory is alive and progressing with many of the brightest young people in physics still wanting to do strings. Incredibly the next three strings conferences in Korea, US and India are already being organised. How many conference series have that many groups keen to organise them?

It has become a tradition for David Gross to give some kind of outlook talk at these conferences and this time he said there were three questions he would like to see answered in his lifetime

- How do the forces of nature unify?
- How did the universe begin and how will it end?
- What is string theory?

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The last of these questions is one he has been asking for quite a few years now. We know string theory only as a small set of perturbative formulations linked together by non-perturbative dualities. There has to be an underlying theory based on some unifying principle and it is important to find it if we are to understand how string theory works at the all-important Planck scale. This time Gross told us that he has heard of something that may answer the question. Firstly he now thinks the correct question to ask is "What are the underlying symmetries of string theory?" and he thinks that work on higher spin symmetries could lead to the answer. What is this about?

For about 16 years it has been known that an important element of quantum gravity is the holographic principle. This says that in order to avoid information loss as black holes, the amount of information in any volume of space must be bounded by the area of a surface that surrounds it in Planck units. This might mean that the theory in the bulk of spacetime is equivalent to a different theory on the boundary. How can that happen? How can it be that all the field variables in the volume of spacetime only carry an amount of information that can be contained on the surface? We can reason that measurement below the Planck length is not possible, but even then there should be at least a few valid field parameters for each plank volume of space. If the holographic principle is right there must be a huge amount of redundancy in this volumetric description of field theory.

Redundancy can be taken to imply symmetry. Each degree of symmetry or dimension of the group Lie algebra tells us that one field variable is redundant and can be taken out by gauge fixing it. In gauge theories we get one set of redundant parameters for each point in spacetime but if the holographic principle is correct there must be a redundancy for almost every field variable in the bulk of spacetime and we will need it to be supersymmetry to deal with the fermions. I call this complete symmetry and I've no idea if anyone else appreciates its significance. It means that the fields of the theory are given by a single adjoint representation of the symmetry. This does not happen in normal gauge theories or in general relativity or even supergravity, but it does happen in Chern-Simons theory in 3D which can be reduced to a 2D WZW model on the boundary, so perhaps something is possible. Some people think that the redundancy aspect of symmetry means that it is uninportant. They think that the field theory can be reformulated in a different way without the symmetry at all. This is incorrect. The redundant nature of the local symmetry hides the fact that it has global characteristics that are not redundant. In holographic theories you can remove all the local degrees of freedom over a volume of space but you are left with a meaningful theory om the boundary.

If there is symmetry for every degree of freedom in the bulk then the generators of the symmetries must match the spin characteristics of the fields. Supergravity only has symmetries corresponding to spin half and spin one fields but it has fields from spin zero scalars up to spin two. String theory goes even further with higher excitations of the string providing an infinite sequence of possible states with unlimited spin. This may be why the idea of higher spin symmetries is now seen as a possible solution to the problem.

Surprisingly the idea of higher spin symmetry as a theory of quantum gravity is far from new. It goes back to the 1980s when it was founded by Vasiliev and Fradkin. It is a difficult and messy idea but recent progress means that it is now becoming popular both in its own right and as a possible new understanding of string theory.

There is one other line of development that could lead to a new understanding of the subject, namely the work on supersymmetry scattering amplitudes. Motl has been following this line of research which he calls the twistor mini-revolution for some time and has a nice summary of the conference talk on the subject by Nima Arkani-Hamed. It evolved partly out of the need to calculate scattering amplitudes for the LHC where people noticed that the long pages of solutions could be simplified to some very short expressions. After much thought these expressions seem to be about permutations and Grassmanians with things like infinite dimensional Yangian symmetry playing a big role. Arkani-Hamed believes that this is also applicable to string theory and could explain the holographic principle. The Grassmanians also link nicely to algebraic geometry and possibly work on hyperdeterminants and qubits.

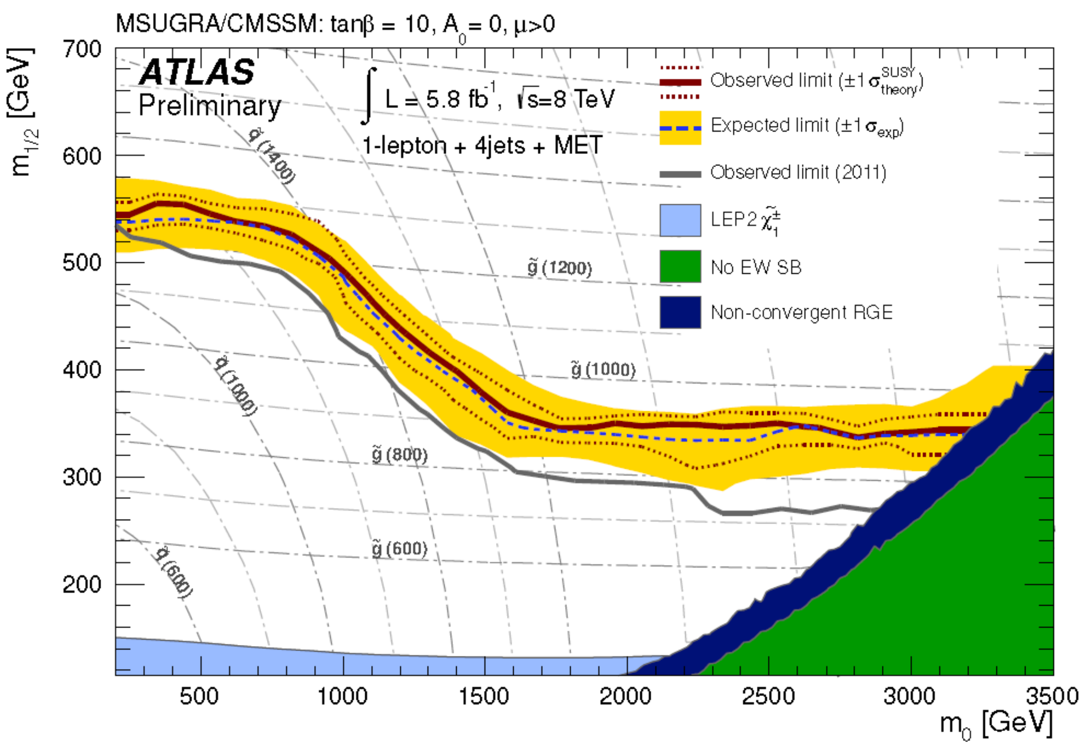
I have to confess that as an undergraduate at Cambridge University in the late 1970s I was completely brainwashed into the idea that symmetry is the route to the underlying principles of nature. At the time the peak of this idea was supergravity and Stephen Hawking - who had just been inaugurated into the Lucasian chair at Trinity college – was one of its greatest advocate. When string theory took over shortly after, people looked for symmetry principles there too but without convincing success. It is true that there are plenty of symmetries in string theory including supersymmetry of course, but different sectors of string theory have different symmetry, so symmetry seems more emergent than an underlying principle. I think the generations of undergraduates after mine were given a much more prosaic view of the role of symmetry and they stopped looking out for it as a source of deep principles.

Due to my brainwashing I have never been able to get over the idea that symmetry will play a huge role in the final theory. I think that all the visible symmetries in string theory are remnants of a much larger hidden symmetry so that only different residual parts of it are seen in different sectors. In the 1990s I developed my own idea of how infinite dimensional symmetries from necklace algebras could describe string theory in a pregeometric phase. The permutation group played a central role in those ideas and was extended to larger string inspired groups with the algebra of string creation operators generating also the Lie algebra of the symmetry. Now that I know about the importance of complete symmetry and higher spin symmetry I recognise that these aspects of the theory could also be significant. Perhaps it is just a matter of time now before string theorists finally catch up with what I did nearly twenty years ago.

In any case it is good to see that there is now some real hope that the very hard problem of understanding string theory from the bottom up may finally have some hope of a solution. It will be very interesting to see how these ideas mature over the next few strings conferences.

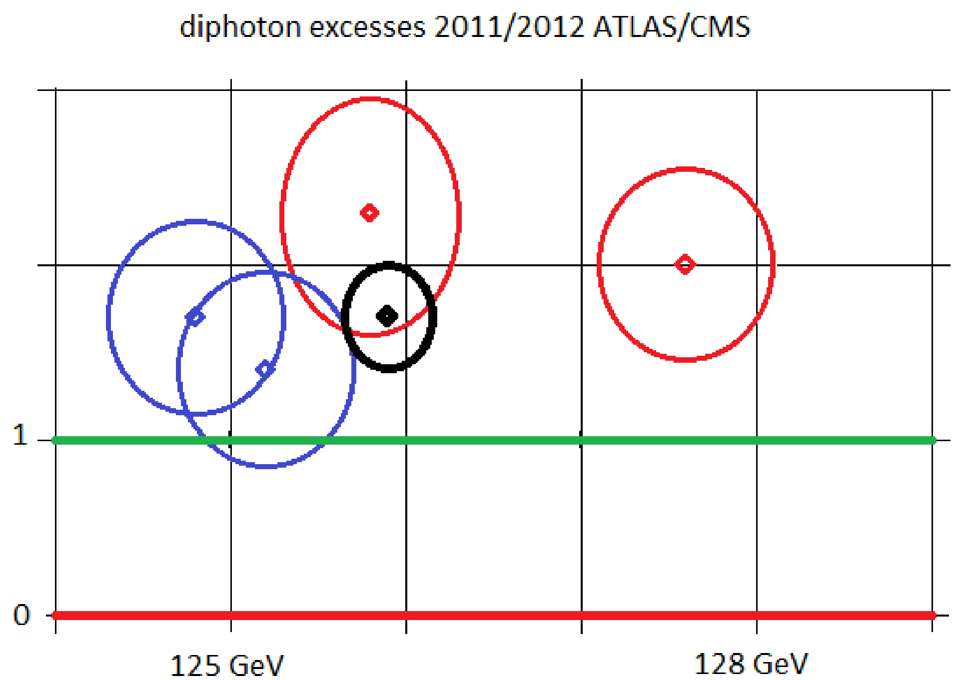
SUSY 2012

The SUSY 2012 conference started in Beijing on August 13, 2012. It is the biggest supersymmetry conference of the year and we expect to see the latest results using the 5/fb gathered in 2012 at 8 TeV before the last technical stop. Actually at least some of the results have already appeared with three new conference notes from ATLAS this morning here, here and here. CMS released their results earlier, see their twiki page.



Because of the high masses being searched for the extra TeV of energy over last year's 7 TeV actually provides 2 to 3 rimes as much sensitivity, so even without combining the new results with the similar amount of data collected last year we get significantly better depth. Sadly there is nothing yet observed in these notes beyond standard model expectations. This is disappointing but there may be other searches released later and there are always places for SUSY to hide from the LHC.

The most promising anomaly at this time is the 1.8 times SM excess in the diphoton channel seen in the Higgs search which currently has 2.5 sigma significance BSM in ATLAS and 1.5 sigma in CMS. If the peaks coincided the combined significance would be about 2.8 sigma but they are at slightly different masses so the combined result is actually no better than ATLAS on its own. You could argue that this might be a callibration error and the 2.8 sigma is good. In any case there will be twice as much data available in a few weeks and we will see if the excess is a statistical fluctuation or not. Looking at the four individual results from the two experiments and last year vs this year they can be plotted on a mass vs signal scale roughly as follows



The green line is the standard model expectation, blue circles are CMS and red are ATLAS. Black is the unofficial combination. The results are comparable to throwing 4 dice and getting four sixes. Was it a fluke or were the dice loaded, and if so, how?

If the effect is not statistical it could easily be a combination of systematic errors. This would most likely be due to errors in the theoretical calculations that would affect both experiments. (TS pointed out this paper which fingers QCD uncertainties) Many people would suggest we wait for the dice to be rolled again and then look at systematics more carefully before taking this too seriously. However, by time that has happened the long shutdown will be on us. If there is a

possibility for something to be seen here it makes sense to look at what it could be. Theorists might then make predictions that could be tested this year if triggers can be adjusted in time.
I am assuming that the excess in the diphoton channel is due to extra particles that affect the Higgs decay loop and that the production rate via gluon fusion is close to SM predictions.

This may be wrong but it is what the data looks like so far. That being the case, the Higgs diphoton loop can most easily be enhanced if there is a new charged particle that adds to the loop. A boson would probably add to the cross-section while a fermion would subtract from it but some knowledgeable theorists say that "vector-like" fermions are also a possibility and who am I to argue. It must be colourless to avoid spoiling the gluon fusion production rate. It could carry lepton number which would affect its decay possibilities. Mass would be greater than 105 GeV otherwise it would be produced via mediated photons at LEP, but less than about 300 GeV to have a significant affect on the loop. Best candidates are scalar leptons like the stau or charged scalars like a charged Higgs, but vectors such as a W' are also possible. These things have been searched for and already excluded in the required mass range, but only under model specific assumptions. Hadron colliders have big blind spots especially when particles decay via jets. There is still hope that something is being missed.

References

1. http://blog.vixra.org/2012/07/31/string-theory-returns-to-symmetry/

2. http://blog.vixra.org/2012/08/13/susy-2012/