Guest Editorial

Physics in a Higgsless World

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The ATLAS and CMS data is giving a $2-\sigma$ exclusion on the light Higgs fields in the $110 - 140GeV$ energy scale. This is a 95% probability of no signal from the Higgs field. The data so far is lack luster for those who promote Higgsian theories, but we are at about 1/1000 the total data expected, so there are lots more to come. In light of the foregoing, the author discusses here Higgsless alternatives. Clearly the time we live in currently is interesting, and we may be in a time where our understanding of the foundations of physics might radically change. The one advantage of living in a time where a lot of physical theory is falsified is that it clears the way for different modes of thought.

The Higgs field was proposed as a way to avoid a problem with regularizing Feynman diagrams and radiative corrections for transverse momenta around 1TeV. Gauge invariance means that a field theory does not adjust the value of observables under a phase change. However, a mass term $m|A|^2$ is not gauge invariant. This problem is averted if there is a scalar field with a quartic potential that is gauge covariant with A. This field a quartic potential in the field with a phase is a renormalizable model. Further at the condensate value for the field the gauge modes are restricted and which give rise to a mass. This prevents the gauge field from becoming zero in one gauge and nonzero in another. The gauge restriction on $SU(2) \times U(1)$ removed a part of the Higgs field doublet, the Goldstone boson, and leaves a massless abelian field identified with electromagnetism. This prevents an overshoot of the regularization cut off of weak interaction physics. At energy scales above the condensate there is more gauge freedom in the theory, and the regularization problem is avoided. The experimental observation of the predicted Z^0 and $W^{\pm}$ particles appeared to be a confirmation of the standard model and that the Higgs field should be "right around the corner."

There are supersymmetric variants of the Higgs model as well. SUSY requires two complex scalar doublets with eight degrees of freedom to properly provide for fermionic mass. These eight degrees of freedom decompose into, three for the longitudinal modes for the $W^{\pm}$ and Z bosons, while the other five degrees of freedom are predicted to become physical scalar bosons. These five define the the minimal supersymmetry statndar model (MSSM) Higgs fields, which are the Light, Heavy, Pseudoscalar, and plus/minus Charged Higgs.

The ATLAS and CMS data is giving a $2-\sigma$ exclusion on the light Higgs fields in the $110 - 140$GeV energy scale. This is a 95% probability of no signal from the Higgs field. The data so far is lack luster for those who promote Higgsian theories, but we are at about 1/1000 the total data expected, so there are lots more to come. Luminosities will improve and in another year or two the picture should be much clearer. The $2-\sigma$ results in the $110 - 150$ GeV Higgs mass range is not a Hindenburg event for the standard model, but it is a Lead Zeppelin. However, Led Zeppelin was always one of my favorite rock bands, so with that in mind we might look on the bright side of this. It should also be pointed out that the INTEGRAL result on the polarization of light at different wavelengths from a Gamma Ray Burstar indicates there is no quantum graininess to spacetime far below the Planck scale. So a vast archive of physics theory and phenomenology appears to be headed for the trash can. However, at the TeV scale of energy it is obvious that something does have to change in physics, so nature is likely to tell us something. We may find that our ideas about the Higgs are nave in some way, or maybe that the entire foundations of physics suffers from some sort of fundamental dysufunction..

The Higgs particle is a form of Landau-Ginsburg potential theory used in phase transitions. Phase transitions are a collective phenomenon. With the Higgs field the thing which transitions is the vacuum. This leads to two possible things to think about. Even if this transition of the vacuum takes place, we expect there to be a corresponding transition with QFT physics of single or a few particles. We might then have a problem that some people are familiar with. In a clean flask you can heat distilled water to

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above the boiling point with no phase change. If you then drop a grain of salt into the flask the water rather violently bumps. By doing single particle on particle scattering we may not have enough degrees of freedom to initiate the phase transition. The phase transition needs a measure of noise we are not providing. It might then be that the Higgs field will turn up in messier heavy ion experiments. The second possibility, which frankly I think might turn out to be the case, is that QFT has a problem with the vacuum. The Higgs field occurs in a large vacuum energy density, which in the light of matters such as the cosmological constant seems fictitious. It is the case QFT becomes a mess at 1-10 TeV, where the Higgs field becomes a sort of regulator which prevents divergences. However, the problem might in fact be that QFT is sick period, and the fix might involve something completely different from anything on the archives of theory. So what sorts of options are available if we live in a Higgs-less world? We might then ponder some possible prospects for physics in such a world that might not bend current physical theory too seriously.

If we are to stay at least somewhat in line with established physical theory, Technicolor is one option for a Higgs-less world. Technicolor is a sort of "transformation" of $T\,\bar{T}$ condensates into another form. Sugawara did this with u-d quarks as a way of constructing meson physics in the $.1\ -\ 1$ GeV range back in the 1970s. This is really a similar idea. In the technicolor theory the "meson" is the Higgs boson. The mechanism for Higgs production most often looked for is $T\,\bar{T}\ \rightarrow\ H$, or equivalently $H\ \rightarrow\ T\,\bar{T}$, where the latter gives the decay channels one searches for as a Higgs signature. This sounds like a small change, one where the field that induces the symmetry breaking has dynamics, and the symmetry breaking process is not spontaneous.

However, Technicolor might lead to something. Suppose there is some momentum scale horizon, which is due to the end of conformal RG flow. This might also have something to do with the $AdS\ \sim\ CFT$, where gluon chains are dual to the quantum gravitation sector (graviton) on the AdS interior. We live on the boundary of the AdS, where there are no gravitons. We may find that attempting to exceed $10TeV$ in energy only gives more of the particles we know in the conformal broken phase. However, with the conformal breaking comes mass, and from mass we have classical gravity. So there may still be signatures of this sort of physics. The technicolor condensate might be a form of gluon chain related in some manner to the graviton. If Technicolor leads to this type of physics, we may then have to search for different observables.

Now let us push forwards with this some. The AdS spacetime has hyperbolic dynamics. A sine-Gordon equation $\phi_{xx}\ -\ \phi_{tt}\ =\ sin(\phi)$ emerges if the dynamics is perturbed by this periodic potential. This potential breaks the chiral symmetry of fields and serves a role similar to the Higgs field. This theory is equivalent to the Thirring fermion model with a quartic potential. Suppose the fundamental field in the AdS is a fermion field with a quartic potential. If these fermions are U-dual to quarks and have some mass there are then Bogoliubov coefficients and physics similar to the BCS theory. These fermion condensates form spin states $s\ =\ 0,\ 1,\ 2$. These boson states are dual or equivalent to quark condensates, such as the Technicolor $T\,\bar{T}$ condensate. Such quark condensates form glue-balls or gluon chains and are an aspect of the $AdS_3\ \sim\ QCD$ duality. Such a model will be supersymmetric.

There are connections with quantum critical points as well in this theory. Recently connections between quantum critical phase transitions and AdS physics has become a growing area of interest. Quantum critical point refers to a phase transition induced by a scale of quantum noise in a system, which serves the role of temperature in classical phase transitions. Such physics scales from the boundary of the AdS, which repels a moving particle, to the event horizon of a BTZ black hole, where the AdS_4 decomposes to $AdS_2 \times S^2$, for AdS_2 with isometry group $SL(2,\ \mathbf{C})$ for conformal quantum mechanics. The behavior of a charged particle with a BPS black hole is analogous to the phase change due to quantum criticality. This approach to phase change is offering alternatives to the standard BPS theory, effectively replacing temperature with the scale of quantum fluctuations, $E/kT\ =\ Et/\hbar$, for t a euclideanized time.

These are some possibilities based upon work of the author. There may be other possibilities as well. We may want to still consider the prospect the Higgs will still manage to show itself. Clearly the time we live in currently is interesting, and we may be in a time where our understanding of the foundations of physics might radically change. The one advantage of living in a time where a lot of physical theory is falsified is that it clears the way for different modes of thought.

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