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WebSights



WebSights features reviews of select sites presenting physics teaching strategies, as well as shorter announcements of sites of interest to physics teachers. All sites are copyrighted by their authors. This column is available as a web page at <http://PhysicsEd.BuffaloState.Edu/pubs/WebSights>. If you have successfully used a site to teach physics that you feel is outstanding and appropriate for *WebSights*, please email me the URL and describe how you use it to teach. The person submitting the best site monthly will receive a T-shirt.

A Theory of Everything

“All fields of the standard model and gravity are united”

Thus begins the abstract of a recent paper by Garrett Lisi. It is quite literally a Theory of Everything, unifying all the known elementary particles and fields. This has created quite a stir; it's not every day that somebody publishes a Theory of Everything. It's too early to say whether this theory is right or even partially right ... but it is not *obviously* wrong, and it is being taken seriously by many experts.

By way of background: originally, magnetic fields and electric fields were considered separate phenomena, but in the mid-1800s they were seen to be part of a single, grander field, now known as electromagnetism. Ever since then, physicists have been trying to find similar relationships among the other fundamental interactions. In the 1960s, the weak nuclear force was united with electromagnetism, forming what is now called the electroweak interaction. At about the same time, several seemingly disparate strong nuclear forces were united, and are now seen as merely different aspects of “the” strong interaction. This work made some spectacular predictions of particles that were later discovered. This work as well as the electroweak unification revolved around symmetry arguments. This is formalized in terms of group theory, Lie groups in particular. The symmetry of electromagnetism is given by the Lie group $U(1)$, the electroweak interaction is $SU(2) \times U(1)$, the strong interaction is $SU(3)$, and the standard model combines the strong and electroweak interactions as $SU(3) \times SU(2) \times U(1)$ plus some additional complications. The standard model is conspicuously silent about gravitation.

Lisi's work is based on another Lie group, a very large group called E_8 . Among other things, he shows how all the elements of the standard model can be found within

E_8 . He finds other elements that he associates with gravitation. There are a handful of remaining elements that he associates with as-yet undiscovered particles.

E_8 is an example of a “simple” Lie group as defined here: http://en.wikipedia.org/wiki/Simple_Lie_group. E_8 is an “exceptional” Lie group in the sense that there is only one member of the E_8 family; this is in contrast to the nonexceptional Lie groups that form infinite families of increasing dimension, such as $SU(2)$, $SU(3)$, $SU(4)$,

The title of Lisi's paper is “An Exceptionally Simple Theory of Everything.” You can see that this is a horrible pun; E_8 is exceptional in a technical sense and simple in a technical sense, but the paper itself is not at all simple in the usual sense. It is exceedingly complicated, although it is perhaps simpler than other recent attempts to formulate a Theory of Everything, such as string theory. The work is not finished. There are many details yet to be worked out. It seems safe to say that nobody on Earth fully understands it, not even Lisi himself.

In the past, the details of such theories would be thrashed out in front of a chalkboard in some famous place. In this case, however, important discussions are taking place on various blogs. This makes the discussions open to observation by the public in a way that would have been unimaginable not too long ago.

The full paper can be downloaded from <http://arxiv.org/abs/0711.0770>. Wikipedia has a nice short overview at http://en.wikipedia.org/wiki/An_Exceptionally_Simple_Theory_of_Everything. Lisi's own personal site is <http://differentialgeometry.org/>. There is a movie showing some rotations of the E_8 root diagram at <http://differentialgeometry.org/anim/e8rotation.mov>. One relevant blog is <http://backreaction.blogspot.com/2007/11/theoretically-simple-exception-of.html>, which begins with an excellent overview of the work, and is followed by a discussion involving some knowledgeable people including Lisi himself. Another relevant blog is <http://www.math.columbia.edu/~woit/wordpress/?p=3D617>.

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