

TRANSCRIPT

08-112-HiggsBoson

A few introductory words of explanation about this transcript.

This transcript includes the words sent to the narrator for inclusion in the latest version of the associated video. Occasionally, the narrator changes a few words on the fly in order to improve the flow. It is written in a manner that suggests to the narrator where emphasis and pauses might go, so it is not intended to be grammatically correct.

The Scene numbers are left in this transcript although they are not necessarily observable by watching the video.

There will also be occasional passages in blue that are NOT in the video but that might be useful corollary information.

There may be occasional figures that suggest what might be on the screen at that time.

105-Intro

Today we will talk about the mechanism that causes fundamental particles to have mass. If the electron had a different mass, then the orbitals inside atoms would be a different size and the world would be a very different place.

110-ClassicalFields

Let's begin by talking about the thing that physicists call a field. The need often arises to describe something that can have a different value at every point in space... like the air temperature or like the wind velocity or like the strength and direction of some force such as the Earth's magnetic field.

There are only four forces that we know of, and they are all described by fields that give their strength and direction at every point in space.

But take note that a force field is something real. It is not just a number for every point in space. It has a physical reality. As John Archibald Wheeler said, "It occupies space. It contains energy. Its presence eliminates a true vacuum." And in the words of Feynman, The field "creates a condition in space."

In classical physics these fields were often thought of as continuous, smoothly changing entities.

115-QuantumFields

But Quantum Mechanics rejects the notion of continuous. And so... fields became distributions of tiny field particles. And the strength of the field at any given point was nothing but the density or quantity of field particles at that point.

These particles are called virtual particles, because they violate the conservation of energy rule for extremely short times in order to exist. They exist because of energy fluctuations allowed by Heisenberg's Uncertainty Principle. But they must disappear quickly because of the same Principle.

In force fields like electric or magnetic fields, these field particles are called gauge bosons. THEY are the physical reality that "occupies space" as described by Wheeler.

And while gauge bosons exist as virtual particles when generated in violation of conservation laws, they can exist as real particles too if they are given enough energy to satisfy the conservation accountant.

120-HiggsField

Most fields in science are generated by some source. An electric field is generated by an electric charge. Take away the source, and the value of the field goes to zero, and Feynman's "condition in space" disappears.

But the Higgs Field is different in this respect. It still has a value – a physical reality -- at every point in space even without a source to generate it. So there really is no "empty space" anywhere. The entire cosmos is saturated with the Higgs Field – all the time – everywhere.

125-HiggsBoson

And because of Quantum Mechanics, this means there has to be a field particle. Enter the Higgs Boson. Virtual Higgs bosons are the quanta of the Higgs field, and they interact with all particles except the photon, the graviton, and the gluons. The strength of the interaction between the Higgs boson and each particle is directly related to the REST mass of that particle. Since the Top quark has the highest rest mass, it also has the strongest interaction with the Higgs. The electron is 300,000 times less-massive than the top quark and so its Higgs interaction is much smaller. And the almost-massless neutrino has only a tiny-tiny interaction.

130-HowMass

Since the Higgs permeates all space, any particle that interacts with the Higgs, interacts with it all the time and everywhere. The Higgs particles act like sticky bits that put a drag on other particles, and it is this drag that we detect as rest mass.

135-Detection

In order to detect a Higgs Boson in the laboratory, we must create a real one instead of a virtual one. We do this by slamming particles and antiparticles together to create fireballs of terrific energy. And out of this fireball we look for decay products that indicate that we created a Higgs boson.

140-HowMany

There may be as many as five Higgs Fields – each with its own boson. And hopefully in the next year or so we will discover how many and how massive they really are.