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The LHC’s latest results deliver another blow to supersymmetry

Supersymmetry: The favourite contender to extend the Standard Model just took a hit.

FIONA MACDONALD

30 JUL 2015

Researchers at CERN have provided new insight into the behaviour of the tiny subatomic particles that make up protons and neutrons, called quarks, and they're consistent with the traditional Standard Model of particle physics.

That's great news for the Standard Model - a set of equations that explains the behaviour and interactions of particles in the Universe - but not so good for the supersymmetry hypothesis, which is a proposed extension that aims to fill in some of the gaps in the Standard Model. And those gaps aren't insignificant: the Standard Model can't explain dark matter and dark energy, or the force of gravity according to Einstein's theory of general relativity.

The new research looked into a specific type of quark called the bottom quark. There are six quark varieties - up, down, charm, strange, bottom, and top. The bottom quarks are heavier than the up and down quarks, and are able to shift their shape. Usually they become charm quarks when they do this, but they've occasionally been observed transforming into up quarks.

By smashing subatomic particles together using the Large Hadron Collider (LHC) in Switzerland, researchers have now calculated exactly how often that happens, and found that only bottom quarks with a left-handed spin decay into an up quark. And that's exactly what the Standard Model, but not the supersymmetry hypothesis, predicts.

"[The result is] entirely consistent with the Standard Model and removes the need for this [supersymmetry] hypothesis," lead researcher Guy Wilkinson told ABC Science. "It would of course have been very exciting if we could show that there was something wrong with the Standard Model - I cannot deny that would have been sensational."

One of the main purposes of the LHC is to try to extend physics beyond the Standard Model, which also can't explain the mass of the mysterious Higgs boson. Many physicists believe that supersymmetry, a hypothesis that suggests there's a heavier 'sibling' for every particle in the Universe, will be the next step.

But despite almost seven years of experimentation, the LHC has failed to find any evidence to support supersymmetry, and plenty of results consistent with the Standard Model. This discovery, which was made after trawling through years of observations on particle decay across the LHC, is just another nail in the proverbial coffin.

"It is one of the most frustrating confirmations we've ever had. We know our theory is incomplete, and this ultra-rare decay may give us clues as to what might replace it," one of the physicists involved, Tara Shears, from the University of Liverpool in the UK, said in a press release.

"What this discovery tells us is that there are no signs yet of our best alternative, a theory called supersymmetry (SUSY)," Shears added. "We haven't ruled out SUSY entirely, but we've definitely dismissed many of the most popular versions of it. We know that there must be new physics, but it's starting to look like this might be stranger than we'd imagined."

The good news is that this kind of measurement was previously assumed to be impossible with the LHC - researchers thought it would take an even more powerful particle collider. And the fact that the collider got an upgraded reboot in April this year suggests that we may soon get even more detailed observations.

And don't worry, supersymmetry isn't dead just yet. "It is very difficult to kill supersymmetry: it is a many-headed monster," Wilkinson told ABC Science. "If nothing is seen in the next couple of years, supersymmetry would be in a much harder situation. The number of true believers would drop."

Matter Antimatter

Anomalies in the Standard Model of Particle Physics

the standard model of particle physics implies that the big bang should have made equal amounts of matter and antimatter. But when matter and antimatter meet, they annihilate in a puff of energy. So neither should have survived the early days of the universe. So the SMPP sees the material universe of matter as an anomaly; ie, it doesn’t explain why matter even exists.

One hint may be differential rates of decay of particles and anti-particles. Some differential decay rates have been observed.

New scientist: the only pub to take in the big picture.

New scientist 27 April 2016

LHC signal hints at cracks in physics' standard model 3 sept 2015

Collider spots same anomaly seen by two other experiments, but more data are needed to claim a discovery.

An intriguing signal from the Large Hadron Collider (LHC) might prove to be the crack that prises apart the standard

model — physicists’ current best description of how matter and forces interact.

Analysis of data gathered during 2011–12 at the collider at CERN, Europe's particle-physics laboratory near Geneva, Switzerland, suggests that in particular decays, short-lived particles called B-mesons create taus more frequently than they create muons. (Taus and muons are heavier cousins of electrons.) But the standard model says that once the particles' mass differences are taken into account, the decays should occur at exactly the same rate. The finding will be published in Physical Review Letters this month (and has been on the arXiv1 pre-print server since June).

The discrepancy in decay rates, spotted at the collider's LHCb experiment, is small and cannot be claimed as a discovery, because the anomaly may be merely a statistical fluctuation that could fade as more data are collected on B-meson decays. Particle physicists' usual threshold for announcing a discovery is, in statistical parlance, 5 sigma; the LHCb signal has reached only 2.1 sigma.

But physicists are excited because the same anomaly has also been seen in results from two previous experiments: the 'BaBar' experiment at the SLAC National Accelerator Laboratory in Menlo Park, California, which reported it in 20122, and the 'Belle' experiment at Japan's High Energy Accelerator Research Organization (KEK) in Tsukuba, which reported its latest results at a conference in May. LHCb's result is "bang on" the previous two, says Mitesh Patel, a physicist at Imperial College London who works on the experiment.

A 2-sigma difference in a single measurement isn't interesting by itself," says Tara Shears, a particle physicist at the University of Liverpool, UK, and a member of the LHCb collaboration. "But a series of 2-sigma differences, found in different types of decay and independently by different people in a different experiment, become very intriguing indeed."

New physics?

Last year, LHCb found a similar bias, with a significance of 2.6 sigma, in decays of another type of B meson, this time a preference to decay into electrons rather than muons. What makes both measurements so exciting is that if the results prove real, they could point to the same underlying new physics, says Shears.

Both biases could potentially be explained, for example, by positing another kind of Higgs boson, which possesses charge and interacts differently with the various particles involved in the decays. Supersymmetry, a popular theory that seeks to extend the standard model, predicts such multiple Higgs bosons, although Patel says that, should the signal prove real, this is just one of many potential explanations.

Don Lincoln, a physicist at another LHC experiment called CMS, cautions that the findings are still most probably a statistical fluctuation or an improperly estimated uncertainty in the experiment. But seeing the discrepancy in multiple places should make people pay attention. "This is clearly something that must be studied in more detail," he says.

The finding is based on data from the LHC's first run, and physicists will have to wait for as long as a year to gather a similar amount of data from the collider's second run, which began on 3 June. In the meantime, the LHCb team will examine other similar decays in existing data to see if further biases emerge, says Patel.

Physicists at CMS and the LHC experiment ATLAS are chasing their own intriguing results. They search for new particles directly (unlike LHCb, which tries to spot such particles by their indirect influence on known decays). Both CMS and ATLAS have seen low-significance 'bumps' within roughly the same mass region of their data — around 2 teraelectronvolts (TeV) — which could be caused by decays of a new particle, although it is not clear whether the findings are entirely compatible. The latest ATLAS paper, available on the arXiv, puts the signal's statistical significance at 3.4 sigma.

Since the 1970s, experiments have time and again proved the accuracy of the standard model. Yet its failure to account for phenomena such as gravity and dark matter leads many physicists to think that it is merely an approximation of another description beneath. Patel says that he finds LHCb's tantalizing results more convincing than those seen by its rival experiments, but would be happy to see either emerge as real as more data and analysis come in. "The standard model has stood for too long, and we'll take its fall in any way it comes."

http://www.nature.com/news/lhc-signal-hints-at-cracks-in-physics-standard-model-1.18307

The LHC finds evidence of particle activity beyond the Standard Model

28 AUG 2015

Researchers at the Large Hadron Collider (LHC) at CERN in Switzerland have found evidence of subatomic particles acting in a way that defies the Standard Model of particle physics - the current best set of equations we have to explain the behaviour and interactions of particles in the Universe.

This Standard Model has served us pretty well so far, but there are some significant holes, the most glaring being the fact that it doesn't account for gravity. So for decades physicists have been trying to find physics occurring beyond the Standard Model, using machines such as the LHC to help them find clues. And now they may finally have a huge lead.

An international team of physicists has found hints of leptons - a specific type of subatomic particle - behaving in strange ways not predicted by the Standard Model. They uncovered this while looking at the decay of particles called B mesons into lighter particles, including two types of leptons: the tau lepton and the muon.

According to a key Standard Model concept called 'lepton universality', all leptons are treated equally by all fundamental forces, which means that all leptons should decay at the same rate, once corrected for any difference in mass. But in the data, the team found a small but notable difference in the predicted rates of decay. This suggests that some type of as-yet undiscovered forces or particles could be interfering.

"The Standard Model says the world interacts with all leptons in the same way. There is a democracy there. But there is no guarantee that this will hold true if we discover new particles or new forces," one of the lead researchers, Hassan Jawahery, from the University of Maryland in the US, said in a press release. "Lepton universality is truly enshrined in the Standard Model. If this universality is broken, we can say that we've found evidence for non-standard physics."

It would be tempting to disregard this finding as an anomaly, if it wasn't for the fact that a similar discovery about lepton decay was made by the BaBar experiment at the Stanford Linear Accelerator Centre in the US in 2012. This experiment also looked at the decay of B mesons, but it achieved this decay by smashing together electrons, rather than the protons that power the LHC.

"The experiments were done in totally different environments, but they reflect the same physical model. This replication provides an important independent check on the observations," University of Maryland physicist Brian Hamilton explained. "The added weight of two experiments is the key here. This suggests that it's not just an instrumental effect - it's pointing to real physics."

The team now needs to confirm their observations with further experiments. The data used for this research were collected during the first run of the LHC between 2011 and 2012 - the same run that found the Higgs boson, which was the last missing piece of the Standard Model. But now that the particle accelerator is on its second run and achieving record-breaking energy levels, they'll have an even better chance of catching the decay in action again.

"We are planning a range of other measurements. The LHCb experiment is taking more data during the second run right now," said Jawahery. "Any knowledge from here on helps us learn more about how the universe evolved to this point. For example, we know that dark matter and dark energy exist, but we don't yet know what they are or how to explain them. Our result could be a part of that puzzle ... If we can demonstrate that there are missing particles and interactions beyond the Standard Model, it could help complete the picture."

The results will be published in the September 4 issue of Physical Review Letters, but have been published on arXiv ahead of time. We can't wait to see what researchers at the LHC find next.

http://www.sciencealert.com/the-lhc-finds-evidence-of-particle-activity-beyond-the-standard-model

Anomaly 2 Unexplained waves disrupt the smooth sea of radiation left over from the big bang

From New Scientist April 27 2016

Cosmology has its standard model. Our model of the universe is based on general relativity, Einstein’s theory of gravity. General relativity’s equations are notoriously complex. Making a workable cosmological model out of them requires a crucial simplifying assumption: that the universe is pretty much the same on all scales and in all directions. This may not be true.

In 2005, Kate Land and João Magueijo of Imperial College London discovered a string of hot and cold spots stretching on an axis across the cosmic microwave background – something entirely incompatible with a uniform universe. The most accurate maps of the CMB to date, courtesy of NASA’s Planck satellite, confirm this.

The anomalies could still be a statistical fluke born out of random variation, says Jo Dunkley, a cosmologist based at the University of Oxford. Efforts are now afoot to measure the polarisation of the CMB. If the polarisation map also contains anomalies, that will strengthen the case for re-examining our cosmic model. That could mean a long, hard look at the homogeneity assumption.

Future surveys of the large-scale structure of galaxies could give us a wider perspective. Meanwhile there is also everyone’s least favourite option: that the universe is, for some unknown reason, just not homogenous or isotropic on any scale.

Anomaly 3 neutrinos

Neutrinos are particles that interact only via the weak nuclear force that governs radioactive decay. Trillions of the lightest type, electron neutrinos, are generated in reactions in the sun and pass through you every second. They will also pass through Earth without a blip.

Fiddly measurements over decades have revealed that a sizable portion of this flux is going missing. This “solar neutrino problem” was resolved conclusively only in 2001, when electron neutrinos were shown to be shape-shifting, or “oscillating”, into muon and tau neutrinos on their way to us. That breakthrough was awarded last year’s Nobel prize in physics.

At that point we might all have lived happily ever after, had not a series of detectors, starting with the Liquid Scintillator Neutrino Detector at Los Alamos Laboratory in New Mexico in the 1990s, begun to see more experimental blips. The blips suggested that there were not merely three types of neutrino, but four – or more. In 2011, an analysis of neutrinos emitted in nuclear reactors found there were too few antineutrinos compared with neutrinos – a shortfall confirmed in February this year by researchers from the Daya Bay reactor neutrino experiment in eastern China.

One possible explanation is that neutrinos briefly oscillate into unobserved “sterile” neutrino states that don’t even interact through the weak force.

Anomaly 4 quantum entanglement

From New Scientist April 27 2016

Quantum entanglement is a consistent effect in the quantum world. It is not the anomaly.

The anomaly comes in what this tells us about our perception of space and time.

This was brought into sharp relief through a series of experiments based on theoretical work done by the Irish physicist John Bell in the early 1960s. He worked out a mathematical way to tell if a measurement on one quantum particle (a photon of light, say) truly could change the result of a measurement carried out on another particle immediately afterwards, or whether some invisible, non-quantum influence was responsible.

Implementing Bell’s test experimentally proved fiddly. The first attempt was made by a team of French physicists in 1981, with the result suggesting that only quantum effects could explain what was observed. But it was only last year that physicists at the University of Delft in the Netherlands devised a version of the test that conclusively ruled out standard information transfer, random particle fluctuations or detector snafus as the source of the effects. “This allows us to certify that the problem is not a feature of a particular setup or a consequence of the way in which an experiment was performed, but really points towards a fundamental feature of nature,” says Jean-Daniel Bancal of the Centre for Quantum Technologies at the National University of Singapore.

And the result is clear. In the quantum world, our normal understanding of space-time, and cause and effect within it, dictated by our intuitive sense of how the world works, does not apply. There is something we are just not getting.

What's also clear is that since photons, electrons and other quantum particles can become entangled and follow these obscure rules, we can begin to devise experiments using them to explore the true nature of space-time. "These are particles we can manipulate," Bancal says.

Anomaly 5 the accelerating universe

New Scientist April 23 2016

distant supernova explosions are consistently dimmer than they should be, indicating they are further away than we expect. The standard explanation – that space's expansion is speeding up thanks to an invisible "dark energy" that makes up two-thirds of the universe's energy – replaces a big anomaly with an even bigger mystery.

Anomaly 6 why is gravity so weak

New scientist April 23 2016

why is the force of gravity so puny compared with the electromagnetic force?

This mismatch between gravity's strength and that of the other forces of nature goes by the name of the hierarchy problem.

the Planck mass, a quantity that gets bigger the weaker gravity is. In our cosmos the Planck mass is huge. It is some 10 quadrillion times bigger than the mass of the W and Z bosons that define the strength of the weak nuclear force, for example. In fact, it is huge compared with all masses that pop up in the standard model. "The question is not why the Planck mass is big; the question is why it is big compared to the masses of all the known particles," says theorist Matt Strassler of Harvard University. "The puzzle is something you can phrase either as the Planck mass being large or particle masses being small."

Explanations following the first route often invoke the idea of "fine-tuning": that we just happen to live in an unnatural part of the universe where gravity is just right, so atoms, stars, planets and people have come to exist. Or they propose large extra dimensions of space into which gravity "leaks", so it appears diluted to us.

Alternatively, we can focus on the Higgs field, which generates particle masses. The low mass of the Higgs boson, discovered in 2012, indicates this field is not particularly strong, keeping all particle masses on the low side.

Such theories focus on as-yet-undiscovered particles or forces whose effect is to restrain the Higgs field to the observed strength of almost – but not quite – zero.

Anomaly 7 weirdly energetic arrivals from space

New Scientist April 23 2016

three neutrinos with anomalously high energies were spotted by the IceCube neutrino detector at the South Pole in 2013 and 2014. They have since been joined by dozens more, all with energies in the petaelectronvolt region – that is, a million billion electronvolts.

In the annals of mysterious cosmic apparitions, these neutrinos have joined the “fast radio bursts” that have been buzzing our telescopes over the past 15 years. Each of these bursts lasts just a few milliseconds, but contains energy equivalent to the sun’s output over the course of a month.

“The Arecibo multiple detection over a period of many days all came from the same location in the sky, so forget a human or alien satellite.”

Anomaly 8 speeding galaxies

studies of galaxies and galaxy clusters consistently indicate that they are rotating too fast for the amount of matter that meets the eye. Try as we might, we haven't yet been able to pin down the culprit – non-interacting "dark matter", which seemingly outweighs normal matter by five to one.