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Methods of STEM Education – Secondary

Nature of Science / Nature of Math Assignment

Due: June 12, 2018

Nature of Science Tenets

Scientific knowledge is open to revision in light of new evidence

This tenet overflows from the article, as it was written to directly address how experimental findings in recent particle physics experiments may lead to a revamping of the Standard Model, the holy grail of all physics on the small and intermediate scales. The author repeatedly makes the claim that the sterile neutrino should not even exist according to the current laws of physics, thereby necessitating a potential revision in our models, provided a five-sigma level of certainty can be achieved, currently sitting at 4.8 (Brown, 2018). While the history of particle physics prior to the Standard Model is such that new experimental results constantly saw further fiddling with scientific models, there has not been a need for revision on the level described by the author, especially since the model actually predicted the existence of one of the most elusive of all particles before it was even first detected: the Higgs Boson.

Scientific knowledge is based on empirical evidence

Alongside the example of neutrino oscillations and other particle physics phenomenon that are used as evidence for the Standard Model, Brown also discusses observed stellar orbits in spiral galaxies, which allow us to measure the amount of mass contained within the galaxy (2018). Although the laws of physics used to determine such mass (e.g. Newton's Law of Universal Gravitation) have been accurately used in other realms, the quantitative work proves inconsistent with the observed mass from observed starlight and stellar models. As such, we have evidence for the presence of missing mass, dubbed "dark matter." While the composition of dark matter is one of the most researched issues in astrophysics, our knowledge/awareness of the existence of something unseen based on what we can see has NOS written all over it.

Science addresses questions about the natural and material world

Science is an ongoing endeavor to further expand and refine models so that they can explain as much of the universe as possible, and the experimental results discussed in the article are a perfect example of that. Multinational, collaborative experiments in LSND, MiniBooNE, etc. pool together data and collective knowledge to improve further on our understanding of neutrinos, an accepted standard for model modification (five sigma) is addressed to discuss potential uncertainties and error, an application of potential new understandings to our understanding of our universe with regards to dark matter is discussed, and so on. Science is a many faceted endeavor to, frankly, address one of the simplest questions of all: why? Even false positives, given some labs were not able to detect sterile neutrino signals, raise new questions that may improve our understanding of how neutrinos interact differently with different experimental setups and equipment.

Nature of Math Tenets

Attend to precision

In particular, when discussing something as significant as the discovery of a new particle, particle physicists, as Brown writes, must attain a level of confidence equivalent to five sigma (five standard deviations). While not *exactly* synonymous with precision of results, there is something to be said here for how they are related. Physicists must be very precise in the predictions made by the Standard Model (i.e. many decimal places) to achieve probabilistic, quantum mechanical predictions on the level of, at most, one part per 3.5 million. As mentioned in the article, being off in the number of neutrinos seen, based on type, is a tell-tale sign something is incomplete in the model generating those predictions.

Make sense of problems and persevere in solving them

Brown first mentions that sterile neutrinos were “spotted” in the mid-1990s, which would mark the beginning of a decades-long hunt to replicate the results (2018). Most recently, for instance, the IceCube particle accelerator analyzed thousands of neutrino events to continue the search for the sterile neutrino, which may illuminate our understanding of dark matter and/or bring about a revision of the Standard Model.

Model with mathematics

As alluded to above, predictions from particle interactions come about from application of the Lagrangian of the Standard Model, a very extensive and complicated formula that can be used to determine mathematics involved in the interactions of quantum fields. In other words, the Standard Model can be expressed in a mathematical form to describe and make predictions about what will happen in nature, having been built up over years of experimental work and pattern recognition for events happening in accelerators. On the other hand, there is no model discussed by Brown for dark matter (because no one knows what it is), though modeling the interaction of gravitational interactions of stars in a galaxy with math does provide the evidence for dark matter.

References

Brown, A. (2018). The ghost particle that shouldn’t exist: Scientists find signs of a ‘sterile neutrino’ that could rewrite the rules of physics and help explain dark matter. *Daily Mail*. Retrieved from http://www.dailymail.co.uk/sciencetech/article-5802895/Sterile-Neutrino-Scientists-evidence-mysterious-particle-SHOULDNT-exist.html.

The ghost particle that shouldn't exist: Scientists find signs of a 'sterile neutrino' that could rewrite the rules of physics and help explain dark matter

- **Mini Booster Neutrino Experiment in Chicago observed the 'ghostly' particle**
- **Scientists have only detected the presence of sterile neutrinos once before**
- **These latest findings could cause physicists to rethink the Standard Model**
- **It could also help solve cosmic mysteries like the existence of dark matter – an unidentified substance that makes up roughly 27 per cent of the universe**

By AARON BROWN FOR MAILONLINE

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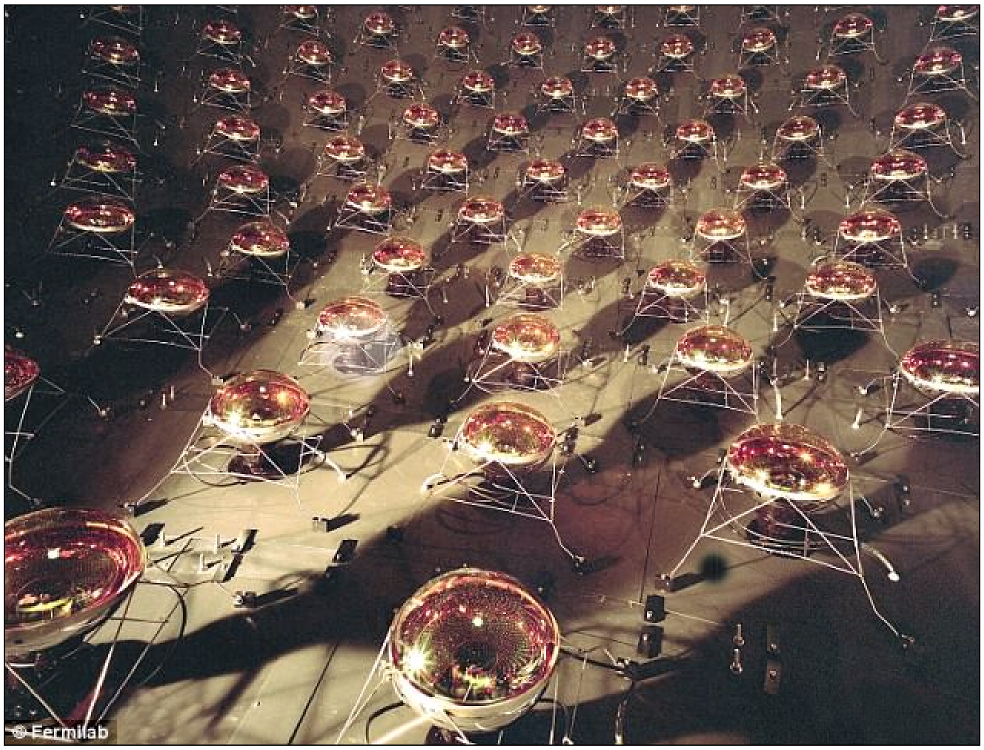
A major physics experiment has detected a 'ghost particle' that shouldn't exist.

Dubbed the 'sterile neutrino', the mysterious particle passes through matter without interacting with it at all.

The particle was first spotted in the mid-1990s in an experiment that left scientists baffled. However, until now, the result of that experiment couldn't be replicated.

If the latest study is confirmed, it could transform the foundations of particle physics.

It could also help solve cosmic mysteries like the existence of dark matter – an unidentified substance that makes up roughly 27 per cent of the universe.



A major physics experiment has detected a 'ghost particle' that shouldn't exist. The Mini Booster Neutrino Experiment, or MiniBooNE, in Chicago fired beams of muon neutrinos at an oil tank to try and detect the presence of sterile neutrinos

Neutrinos are one of the most abundant particles in the universe. As you read this, trillions of neutrinos are travelling through your body.

The particles have almost no mass and rarely interact with matter, meaning they are unlikely to have any impact on the particles of your body, and earning them the 'ghostly' description.

As waves of neutrinos pass through space, they will periodically 'oscillate' — switching back and forth between one 'flavour' and another.

Physicists have already identified three 'flavours' of neutrino: muon, electron, and tau – but in recent decades, several scientists have hypothesised about the presence of a fourth type of particle, the 'sterile neutrino'.

Discovering an additional form of neutrino could help to explain the mysterious origins of dark matter.

Researchers working on the MiniBooNE believe they have observed neutrinos oscillating into hidden, so-called sterile neutrinos, which are impossible for the detector to identify

'That would be huge; that's beyond the standard model; that would require new particles ... and an all-new analytical framework,' Kate Scholberg, particle physicist at Duke University told **LiveScience**.

The hypothetical sterile neutrino has mass, according to the researchers, different from the other types.

Along with this, it interacts only gravitationally, making it extremely difficult to detect.

But, it can be 'caught' by observing its influence on the other types of neutrinos.

This is what happened during an experiment at MiniBooNE (Mini Booster Neutrino Experiment) at the Fermi National Accelerator Laboratory (Fermilab), located near Chicago.

The MiniBooNE experiment involved firing beams of muon neutrinos at an oil tank.

Some of those neutrinos oscillated into electron neutrinos, which produced flashes of light that researchers were able to record using detectors inside the oil.

The oscillation rate is predictable, so even a few extra electron neutrinos would be a result.

The researchers saw 2,437 interactions, about 460 more than predicted.

WHAT IS A 'STERILE' NEUTRINO?

The sterile neutrino is a hypothetical fourth type of neutrino.

So far, there are three known types of neutrinos, known as 'favours'.

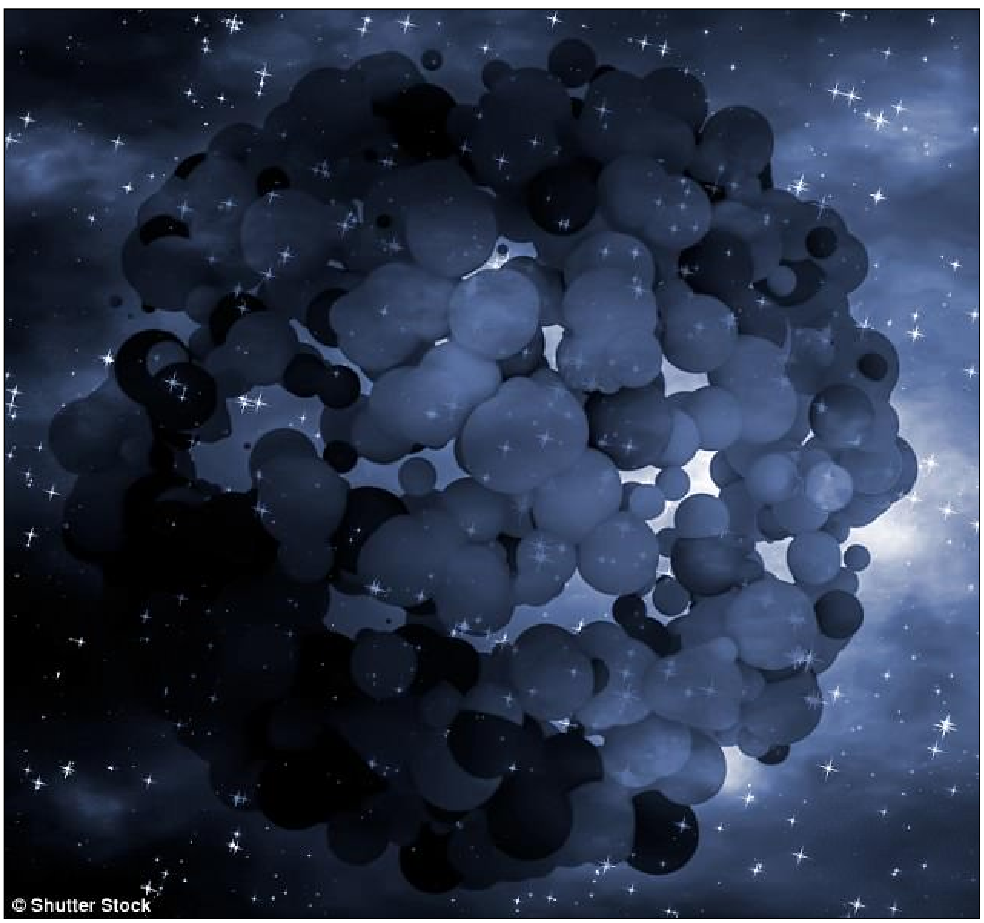
These are muon, electron, and tau.

A fourth type would have mass – different from the others – and interact with gravity.

Studies have suggested it can be 'caught' by observing its influence on the other types of neutrinos.

Most recently, researchers working on the MiniBooNE (Mini Booster Neutrino Experiment) in Chicago believe they observed neutrinos oscillating into sterile neutrinos, and then back to particles in the detectable realm.

If discovered, the sterile neutrino could help to explain the mysterious origins of dark matter, and even resolve issue of the universe's matter and antimatter imbalance.



Discovering a fourth 'flavour' of neutrino could help to explain the mysterious origins of dark matter, and even resolve issue of the universe's matter and antimatter imbalance (Stock)

The results mirror those seen in the Liquid Scintillator Neutrino Detector (LSND), an experiment at the now-decommissioned Los Alamos National Laboratory in New

Mexico back in the mid-1990s — the only other experiment which has detected the presence of sterile neutrinos.

'We have two very different detectors...and we have the same results,' MiniBooNE physicist En-Chuan Huang said.

Both experiments found more neutrino detections than are possible to explain with the Standard Model's description of neutrino oscillation, researchers claim.

Researchers working on the MiniBooNE believe neutrinos are oscillating into hidden, heavier, sterile neutrinos which are impossible for the detector to identify, before they oscillate back into the detectable realm.

The latest findings brought the MiniBooNE team to a 4.8 sigma result, when 'discovery' in particle physics demands five-sigma.

If these results are confirmed, it could help to explain the existence of dark matter.

Like the hypothesised sterile neutrinos, dark matter only appears to interact with regular matter via gravity.

This shared trait is why sterile neutrinos are one of the most plausible candidates for dark matter.

Although dark matter has never been directly observed, scientists are confident that it exists, predominantly because of the gravitational effects it appears to exert on galaxies in our universe.

Dark matter, which is invisible to light and other forms of electromagnetic radiation, would explain a number of inconsistencies in the observable universe.

For example, the Standard Model suggests stars on the fringes of a spinning, spiral galaxy should travel slower than those located close to the galactic centre, where visible matter is more concentrated.

However, in reality, observations have shown stars orbit more or less the same speed – regardless of where they are found in the spiral galaxy.

Scientists believe the gravitational effects of an unseen mass, slowing the speed of the stars at the edge of the spiral galaxy, could explain the perplexing phenomenon.

Identifying the particle that makes up dark matter would be a monumental discovery.

According to Professor Scholberg, if the LSND and MiniBooNE were the only neutrino experiments undertaken on Earth, scientists would be updating the Standard Model to include some sort of sterile neutrino at this very moment.

However, the problem is that other major neutrino experiments have not detected the same anomaly that both LSND and MiniBooNE have observed.

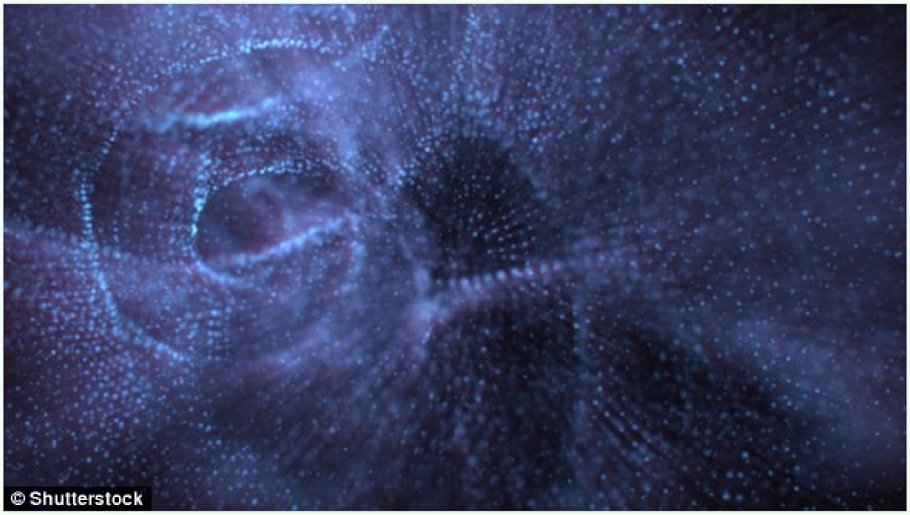
WHAT IS DARK MATTER?

Dark matter is a hypothetical substance said to make up roughly 27 per cent of the universe.

The enigmatic material is invisible because it does not reflect light, and has never been directly observed by scientists.

It cannot be seen directly with telescopes, but astronomers know it to be out there because of its gravitational effects on known matter.

The European Space Agency says: 'Shine a torch in a completely dark room, and you will see only what the torch illuminates.



Dark matter is a hypothetical substance said to make up roughly 27 per cent of the universe. It is thought to be the gravitational 'glue' that holds the galaxies together (artist's impression)

'That does not mean that the room around you does not exist.

'Similarly we know dark matter exists but have never observed it directly.'

Dark matter is thought to be the gravitational 'glue' that holds the galaxies together.

Just five per cent the observable universe consists of known material such as atoms and subatomic particles.

As recently as last year, the IceCube particle detector at the South Pole failed to turn up any evidence for sterile neutrinos.

Researchers working in Antarctica performed two independent analyses which determined with 99 per cent certainty that the eV-mass sterile neutrino does not exist.

Francis Halzen, a University of Wisconsin-Madison professor of physics and principal investigator for the IceCube Neutrino Observatory, said: 'Like Elvis, people see hints of the sterile neutrino everywhere.

'There was this collection of hints, and theorists were convinced it exists.'

After analysing roughly 100,000 neutrino events at the IceCube particle detector at the South Pole (pictured above) in search of the 'sterile neutrino,' scientists working on the project concluded that no such particle exists

It is possible the anomaly detected in the LSND and MiniBooNE could be the result of the way neutrinos interact with the experimental setup, which is not yet not understood.

However, it is entirely possible researchers working at particle detectors around the world will now have to explain why their experiments are failing to produce evidence of the sterile neutrinos which are being spotted in Fermilab and Los Alamos Lab.

'There are people who doubt the result,' Professor Scholberg said, 'but there's no reason to think there's anything wrong [with the experiment itself].'

If that's the case, scientists may have to revise their entire understanding of the universe.

WHAT IS THE STANDARD MODEL OF PHYSICS?

The theories and discoveries of thousands of physicists since the 1930s have resulted in a remarkable insight into the fundamental structure of matter.

Everything in the universe is found to be made from a few basic building blocks called fundamental particles, governed by four fundamental forces.

Our best understanding of how these particles and three of the forces are related to each other is encapsulated in the Standard Model of particle physics.

All matter around us is made of elementary particles, the building blocks of matter.

These particles occur in two basic types called quarks and leptons. Each consists of six particles, which are related in pairs, or 'generations'.

All stable matter in the universe is made from particles that belong to the first generation. Any heavier particles quickly decay to the next most stable level.

There are also four fundamental forces at work in the universe: the strong force, the weak force, the electromagnetic force, and the gravitational force. They work over different ranges and have different strengths.

Gravity is the weakest but it has an infinite range.

The electromagnetic force also has infinite range but it is many times stronger than gravity.

The weak and strong forces are effective only over a very short range and dominate only at the level of subatomic particles.

The Standard Model includes the electromagnetic, strong and weak forces and all their carrier particles, and explains well how these forces act on all of the matter particles.

However, the most familiar force in our everyday lives, gravity, is not part of the Standard Model, and fitting gravity comfortably into this framework has proved to be a difficult challenge.

Read more:
A Major Physics Experiment Just Detected A Particle That Shouldn't Exist

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