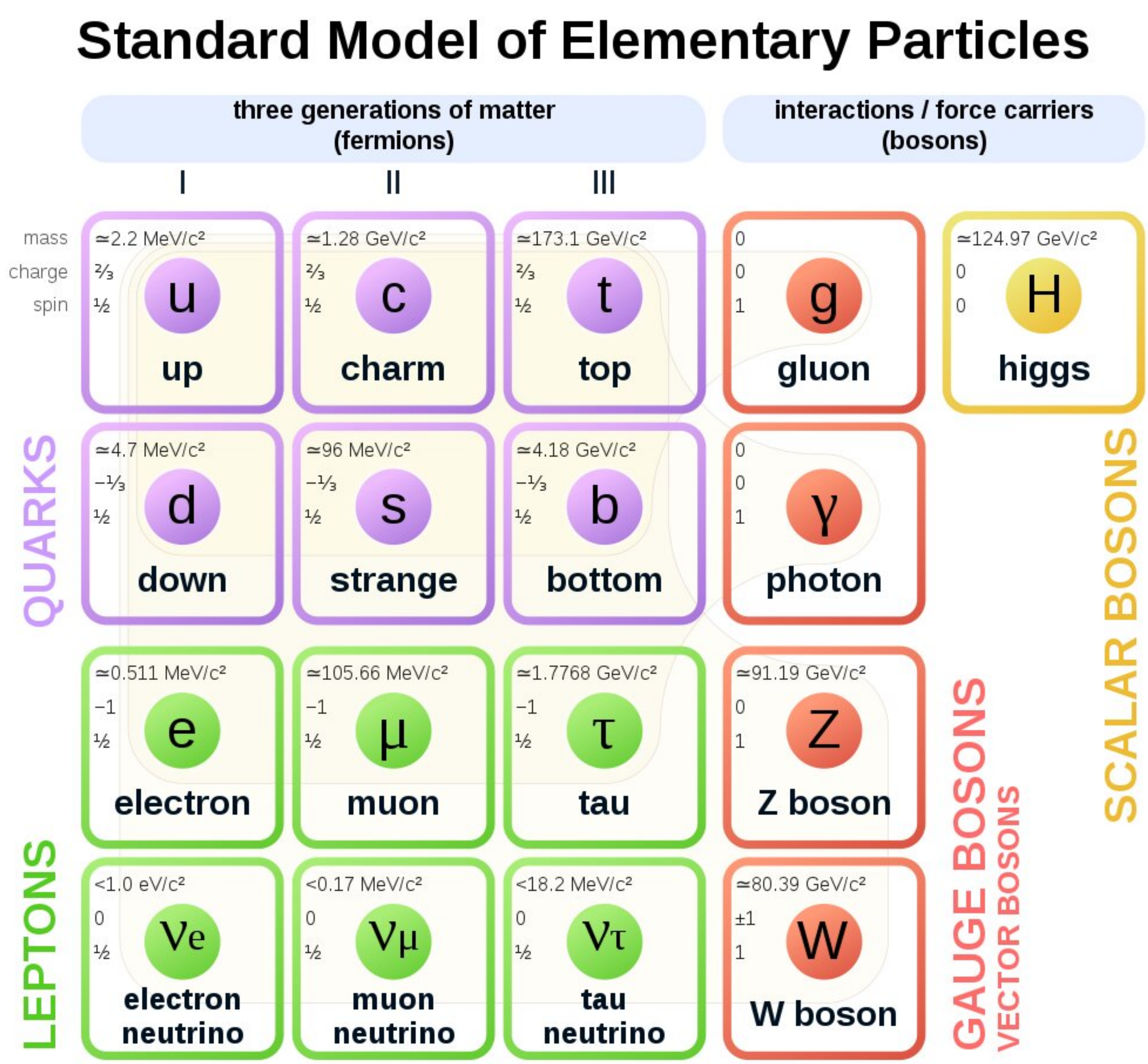
A fifth fundamental force could really exist, but we haven't found it yet

November 27 2019, by Brian Koberlein



Particles and interaction bosons of the standard model. Credit: Particle Data

Group

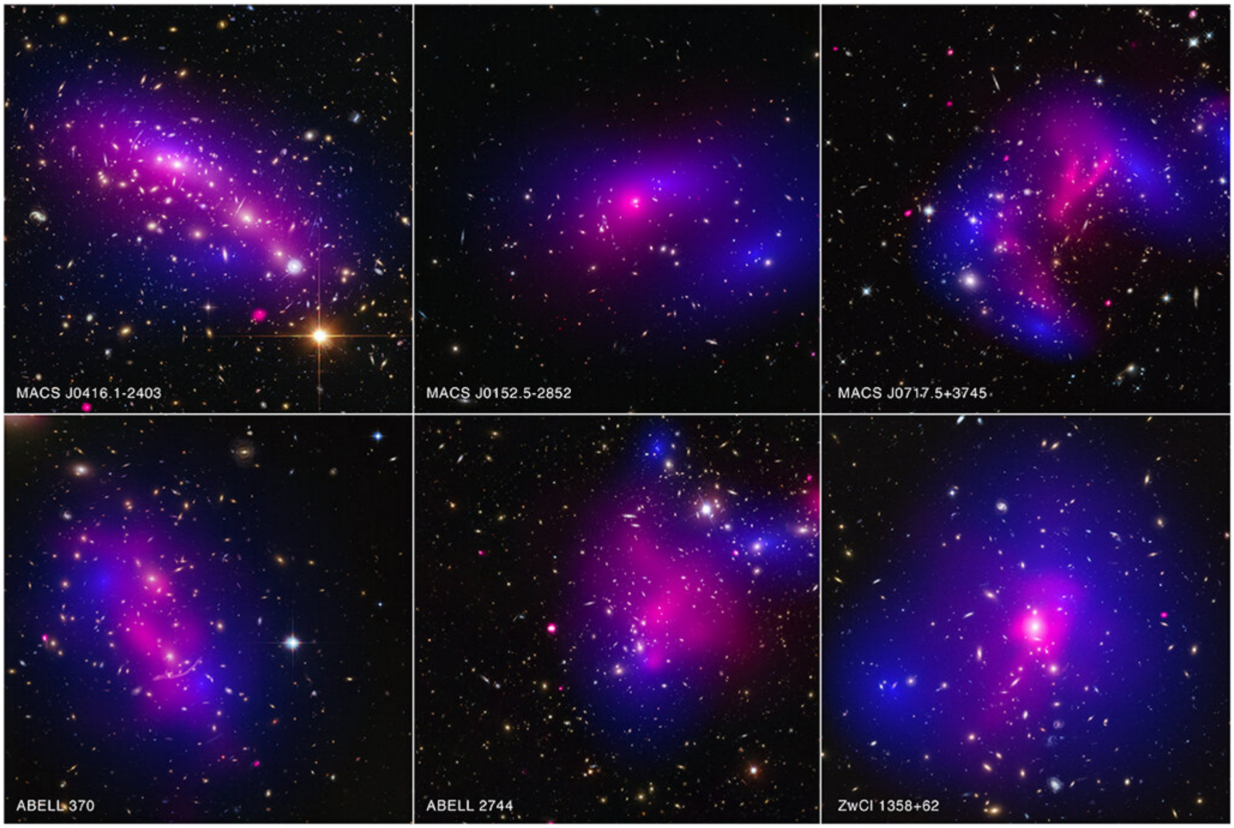
The universe is governed by four fundamental forces: gravity, electromagnetism and the strong and weak nuclear forces. These forces drive the motion and behavior of everything we see around us. At least, that's what we think. But over the past several years, there's been increasing evidence of a fifth fundamental force. New research hasn't discovered this fifth force, but it does show that we still don't fully understand these cosmic forces.

The fundamental forces are a part of the Standard Model of particle physics. This model describes all the quantum particles, including electrons, protons, antimatter and others. Quarks, neutrinos and the Higgs boson are all part of the model.

The term "force" in the model is a bit of a misnomer. In the Standard Model, each force is the result of a type of carrier boson. Photons are the carrier boson for electromagnetism. Gluons are the carrier bosons for the strong interaction, and bosons known as W and Z are for the weak interaction. Gravity isn't technically part of the Standard Model, but it's assumed that quantum gravity has a boson known as the graviton. We still don't fully understand quantum gravity, but one idea is that gravity can be united with the Standard Model to produce a grand unified theory (GUT).

Every particle we've ever discovered is a part of the Standard Model. The behavior of these particles matches the model extremely accurately. Scientists have looked for particles beyond the Standard Model, but so far, they have never found any. The Standard Model is a triumph of scientific understanding. It is the pinnacle of quantum physics.

But we've started to learn it has some serious problems.



Observations of galaxies show the distribution of dark matter. Credit: X-ray: NASA/CXC/Ecole Polytechnique Federale de Lausanne, Switzerland/D.Harvey & NASA/CXC/Durham Univ/R.Massey; Optical & Lensing Map: NASA, ESA, D. Harvey (Ecole Polytechnique Federale de Lausanne, Switzerland) and R. Massey (Durham University, UK)

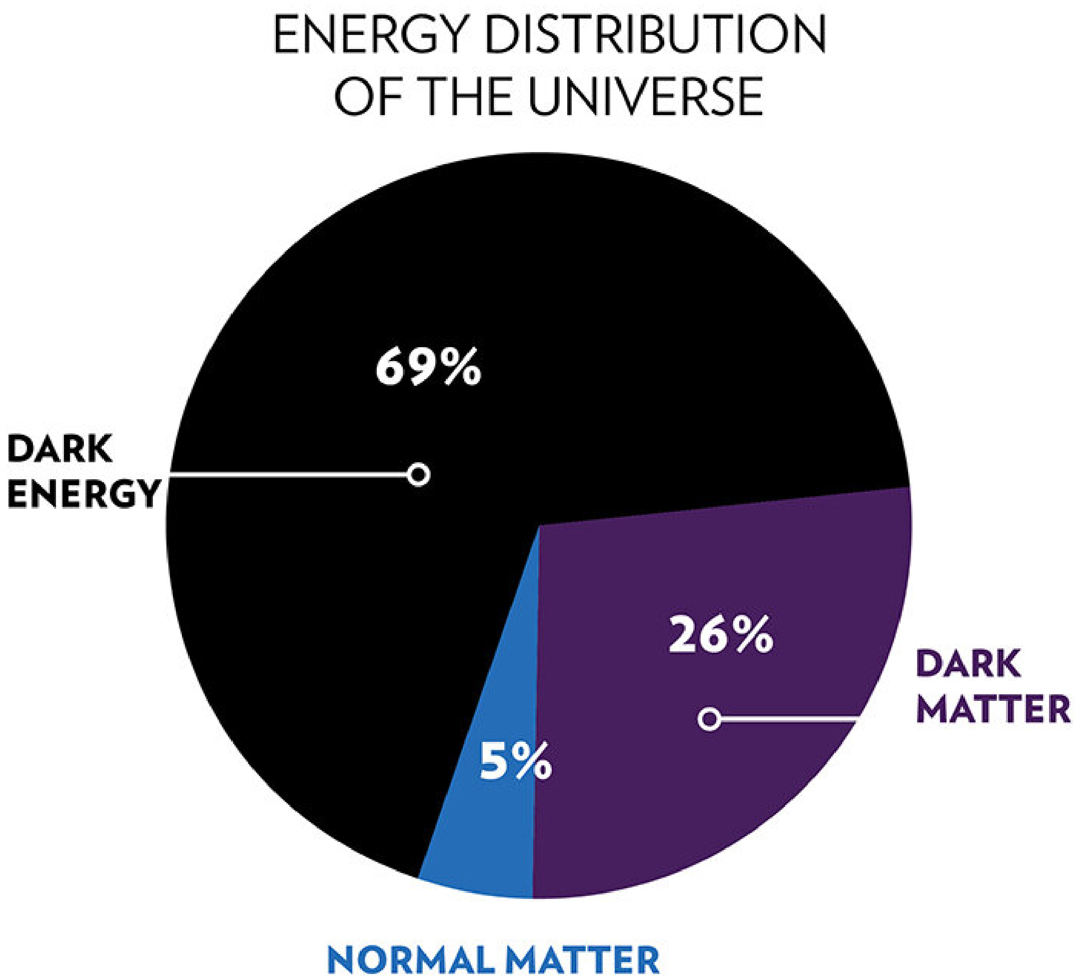
To begin with, we now know the Standard Model can't combine with gravity in the way that we thought. In the Standard Model, the fundamental forces "unify" at higher energy levels. Electromagnetism and the weak combine into the electroweak, and the electroweak unifies with the strong to become the electronuclear force. At extremely high energies the electronuclear and gravitational forces should unify. Experiments in particle physics have shown that the unification energies don't match up.

More problematic is the issue of dark matter. Dark matter was first proposed to explain why stars and gas on the outer edge of a galaxy move faster than predicted by gravity. Either our theory of gravity is somehow wrong, or there must be some invisible (dark) mass in galaxies. Over the past 50 years, the evidence for dark matter has become really strong. We've observed how dark matter clusters galaxies together, how it is distributed within particular galaxies, and how it behaves. We know it doesn't interact strongly with regular matter or itself, and it makes up the majority of mass in most galaxies.

But there is no particle in the Standard Model that could make up dark matter. It's possible that dark matter could be made of something such as small black holes, but astronomical data doesn't really support that idea. Dark matter is most likely made of some as-yet undiscovered particle, one the Standard Model doesn't predict.

Then there is dark energy. Detailed observations of distant galaxies show that the universe is expanding at an ever-increasing rate. There seems to be some kind of energy driving this process, and we don't understand how. It could be that this acceleration is the result of the structure of space and time, a kind of cosmological constant that causes the universe to expand. It could be that this is driven by some new force yet to be discovered. Whatever dark energy is, it makes up more than two-thirds of the universe.

All of this points to the fact that the Standard Model is, at best, incomplete. There are things we are fundamentally missing in the way the universe works. Lots of ideas have been proposed to fix the Standard Model, from supersymmetry to yet undiscovered quarks, but one idea is that there is a fifth fundamental force. This force would have its own carrier boson(s) as well as new particles beyond the ones we've discovered.



We don’t understand most of the universe. Credit: Chandra X-ray Observatory

This fifth force would also interact with the particles we have observed in subtle ways that contradict the Standard Model. This brings us to a new paper claiming to have evidence of such an interaction.

The paper looks at an anomaly in the decay of helium-4 nuclei, and it builds off an earlier study of beryllium-8 decays. Beryllium-8 has an unstable nucleus that decays into two nuclei of helium-4. In 2016, the team found that the decay of beryllium-8 seems to violate the Standard Model slightly. When the nuclei are in an excited state, it can emit an electron-positron pair as it decays. The number of pairs observed at larger angles is higher than the Standard Model predicts, and is known as the Atomki anomaly.

There are lots of possible explanations for the anomaly, including experiment error, but one explanation is that it's caused by boson the team named X17. It would be the carrier boson for a (yet unknown) fifth fundamental force, with a mass of 17 MeV. In the new paper, the team found a similar discrepancy in the decay of helium-4. The X17 particle could also explain this anomaly.

While this sounds exciting, there's reason to be cautious. When you look at the details of the new paper, there's a bit of odd data tweaking. Basically, the team assumes X17 is accurate and shows that the data can be made to fit with their model. Showing that a model can explain the anomalies isn't the same as proving your model does explain the anomalies. Other explanations are possible. If X17 does exist, we should have also seen it in other particle experiments, and we haven't. The evidence for this "fifth force" is still weak.

The fifth force could exist, but we haven't found it yet. What we do know is that the Standard Model doesn't entirely add up, and that means some very interesting discoveries are waiting to be found.

More information: A.J. Krasznahorkay, et al. New evidence

supporting the existence of the hypothetic X17 particle. arXiv:1910.10459v1 [nucl-ex]: arxiv.org/abs/1910.10459

A.J. Krasznahorkay, et al. Observation of Anomalous Internal Pair Creation in ^{8}Be: A Possible Signature of a Light, Neutral Boson. arXiv:1504.01527v1 [nucl-ex]: arxiv.org/abs/1504.01527

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