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NEW CONTENDERS EMERGE FOR DARK MATTER TITLE

By Anil Ananthaswamy

IT'S the top contender for dark matter, the stuff thought to make up 90 per cent of the mass of the universe. Yet is the hypothetical neutralino particle really the best candidate? By reassessing the reasons for making the neutralino the front runner, physicists have opened up the field to many other dark matter candidates.

The neutralino has captivated cosmologists because it wasn't dreamed up to explain dark matter. Rather, it popped out of theories trying to address problems in the standard model of particle physics, which attempts to explain all the known particles that make up normal matter and the forces that affect them. For instance, the standard model cannot explain why the weak nuclear force is so much stronger than gravity.

The theory of supersymmetry was developed to explain such discrepancies. As yet unconfirmed, it says that every particle in the standard model has a heavier supersymmetric partner.

As the universe cooled after the big bang, the heavier supersymmetric particles would have decayed into lighter ones, leaving only one type behind - the stable neutralino. When physicists calculated the properties of this type of neutralino, they were surprised to find that the resulting matter the particles would form in the early universe would have just the right density - also called relic density - to be dark matter.

Yet supersymmetry theory also says that as the universe cooled after the big bang, these heavier supersymmetric particles may have ended up in different "sectors" of the universe, shadowy realms which sit right next to ours but barely interact with our own.

Now Jonathan Feng and Jason Kumar of the University of California, Irvine, have shown that some of these hidden sectors could contain particles very different to the neutralino, and could also form dark matter with the right relic density. If this is so, it could prompt a radical rethink of our picture of dark matter.

Feng and Kumar considered how such hidden sectors might interact with ours. They point out that there are two mechanisms for this, one being gravity. The other is via the exchange of exotic particles. Such particles might just show up at the Large Hadron Collider at the CERN particle physics laboratory near Geneva, Switzerland, which is due to fire up later this year.

In the past, physicists have mostly ignored the possibility explored by Feng and Kumar, because the particles in such hidden sectors did not seem to have the right properties to be dark matter.

The pair say that this need not be the case. Their calculations show that these sectors could be home to several types of stable particle, both lighter and heavier than the neutralino (www.arxiv.org/abs/0803.4196). "The stable particles have a relic density which is just about right to be the dark matter we observe, and that's the really fascinating thing," says Kumar.

John March-Russell of the University of Oxford is impressed. "This opens up new ways that dark matter could communicate with us, and new possible candidates for dark matter," he says.

What's more, March-Russell and his colleagues think they can do away with the exotic particles required by Feng and Kumar's theory. "There is another way, and that is via the Higgs," he says.

The Higgs particle is thought to give all other particles in the universe their mass. Theories of supersymmetry predict multiple Higgs particles, some of which are charged. March-Russell's calculations show that dark matter in these hidden sectors could manifest itself in our sector of the universe through the exchange of charged Higgs particles (www.arxiv.org/0801.3440v2). The Higgs "could be talking to us quite strongly, but it is veiled from our current experimental reach", he says.

The bad news is that the dark matter particles in these hidden sectors are themselves beyond the reach of current experiments, such as the Cryogenic Dark Matter Search (CDMS) in Soudan, Minnesota, as they are predicted to be much heavier than the neutralino. "Planned detectors could just about see it, but it does make the search harder," says March-Russell.

However, it might be possible to spot these heavier dark matter particles by watching for a telltale phenomenon in our universe. If these particles accumulate and annihilate each other in certain regions of the universe, we should see high-energy gamma rays and cosmic rays being emitted.

"Precisely where in the sky you should look, and what the signals will be, is what we are studying at the moment," says March-Russell.