SCIENTIFIC AMERICAN

News - November 10, 2008

New Theories May Shed Light on Dark Matter

The stuff of mystery may be more than meets the eye

By John Matson

If current theories prove correct, ordinary matter—all that we can see, smell and touch—makes up just a fraction, maybe 4 percent, of the universe. The rest comes from the so-called dark sector: dark matter and dark energy, a mysterious and pervasive energy that is suspected of speeding the universe's expansion. Dark matter, so known because it refuses to emit or interact with light in a way that we can see, is nearly six times as prevalent as ordinary matter. But, for all its ubiquity, it is often tagged as being fairly bland, a sort of galactic deadweight that only reveals itself through its gravitational pull.

New theories about the hidden life of dark matter aim to shed this dull image once and for all. Whereas dark matter may not mix much with the ordinary kind, it may tango with other dark matter particles via some new force—one outside the purview of the Standard Model of particle physics.

A group of researchers at the California Institute of Technology proposes that dark matter could have its own force analogous to electromagnetism—mediated, naturally, by "dark photons". Just as in regular electromagnetism, the force would act over long ranges, and the photon (the discrete unit of light energy) would be massless. As noted by study co-author Sean Carroll, a Caltech physicist, on the blog *Cosmic Variance,* the theory opens the door to a rich, as yet unseen world of dark radiation, even dark magnetic and electric fields.

Such a proposal is not merely pie-in-the-sky conjecturing. "As astrophysical observations and simulations improve, we're doing increasingly precise comparisons between the models of how galaxies form and the observations of what galaxies actually look like," Carroll says. "And right now, there are some slight discrepancies." Those discrepancies, he adds, could result from imperfect measurements or "they might be because the idea of completely noninteracting dark matter isn't good enough, that there really are interactions that are affecting the shapes of galaxies."

"Particle physicists have at least known about the possibility of dark radiation for a long time," Carroll says, "but they haven't been taking seriously the idea that it could actually affect the dark matter in our universe." (As Carroll notes on *Cosmic Variance,* another recent paper, co-authored by physicist and cosmologist Jonathan Feng of the University of California, Irvine, also proposes the concept of dark photons, albeit in a different theoretical framework.)

In a separate paper, submitted to *Physical Review D,* a group of researchers at the Institute for Advanced Study in Princeton, N.J., Harvard University and New York University (N.Y.U.) also posits a new dark force, this one with a much smaller range, acting only on nuclear scales. Their theory first sought to account for a wealth of gamma rays emanating from the center of our galaxy, picked up by the European Space Agency's Integral satellite, that correspond to the annihilation of electrons with their antiparticle, positrons (positively charged counterparts to electrons).

Where those positrons were coming from was an open question. "Supernovae make positrons, but not nearly enough," says Harvard astronomer Douglas Finkbeiner, a study co-author. Under the right circumstances, he thought, dark matter could fit the bill. As it turned out, with the help of a new dark force, interacting particles could trade in some of their kinetic energy to produce a positron–electron pair, a proposal put forth by Finkbeiner and study co-author Neal Weiner, an N.Y.U. physicist, last year. But new data from the PAMELA instrument, which detects antimatter in cosmic radiation from on board a Russian satellite, revealed a still surprisingly high number of positrons. So Finkbeiner and his colleagues honed the theory to account for the PAMELA results, redefining how dark matter particles annihilate into other particles. Another space-borne observer, NASA's orbiting Fermi Gamma-ray Telescope (formerly known as GLAST) will provide further guidance in the near future by examining the types of gamma rays coming from areas where dark matter should be clumped. If the group's theory is correct, Fermi's results "really should be distinct from what people were expecting for other kinds of dark matter," Finkbeiner says.

The implications for such a model "go on and on," he says, pointing to the formation of black holes and the heating of galaxy clusters, for starters. "There are all these problems in astrophysics where it seems like you need a little bit more energy, almost as if there's energy coming out of nowhere, so we think this might be what's involved."

This is not the first time that new forces acting on the dark sector have been proposed. At the January 2007 meeting of the American Astronomical Society in Seattle, N.Y.U. professor of physics Glennys Farrar presented findings that pointed to the existence of a long-range force acting on dark matter that would have significant observable effects in the cosmos. Farrar later concluded that the figures on which the proposal was based, relating to the speed of a subcluster of galaxies in the Bullet Cluster, were inaccurate.

Finkbeiner acknowledges that theories such as those of his group often fall short. But paraphrasing the late Princeton University cosmologist David Wilkinson, he says, "most all of your ideas are wrong, so you should find that out as quickly as possible so you can get on to the next one." Whatever the correct idea turns out to be, in whatever complex dance of particles and forces physicists find to best describe the universe, maybe dark matter won't be such a wallflower after all.

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