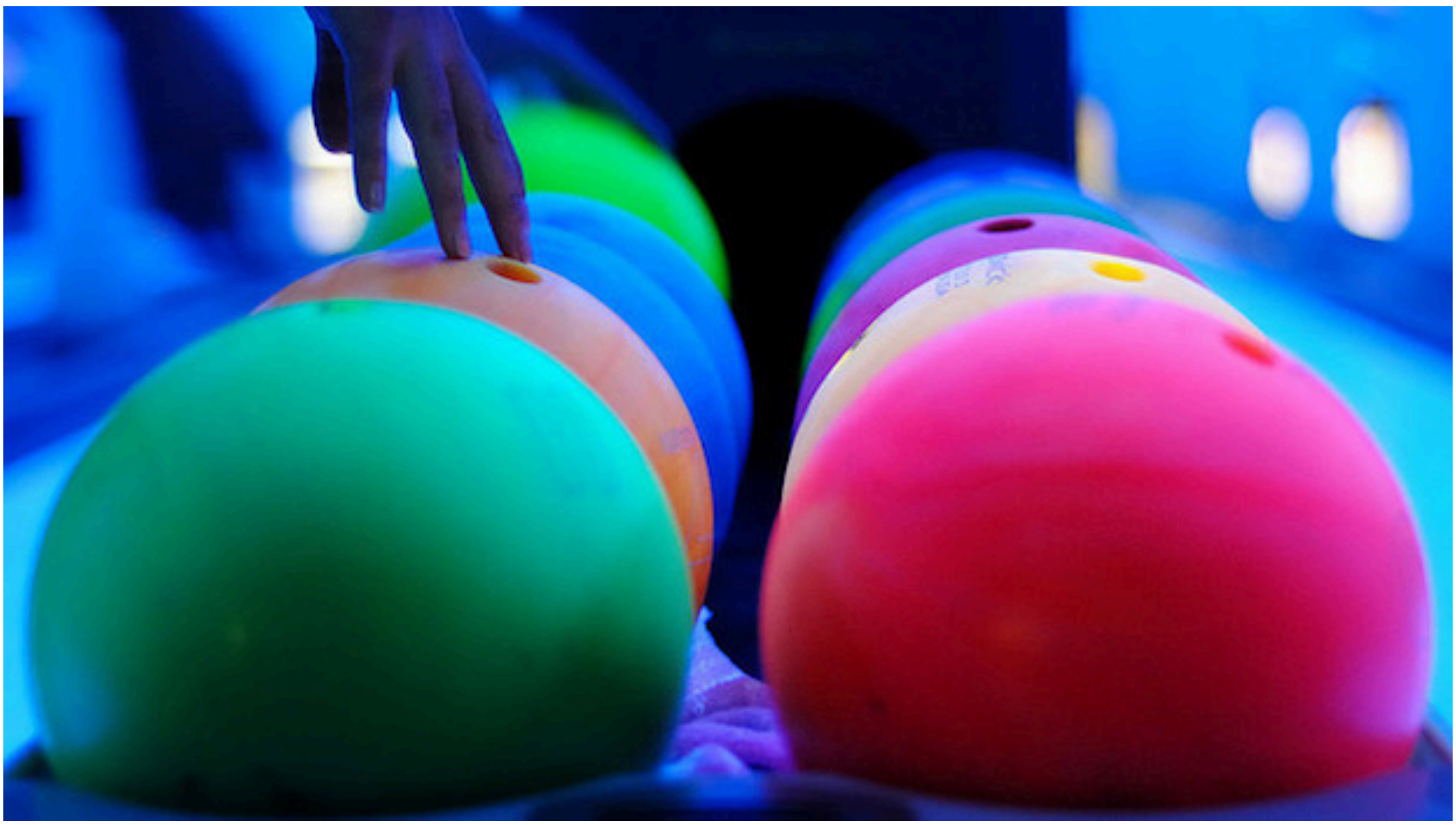
The Nature of Reality

PARTICLE PHYSICS

Bowling for Dark Matter

By Maggie McKee on Thu, 15 Oct 2015

Could 1,000-ton "bowling balls" of dark matter be rolling around the cosmos? That's the idea behind macro dark matter, a proposal that dark matter might actually be a new, outsize species of ordinary matter rather than a completely alien kingdom of particles. That, some argue, could explain why the mysterious stuff has so far eluded capture in exotic dark-matter traps around the world and failed to materialize in the Large Hadron Collider in Switzerland.



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But others say the proposal is no less speculative than those that conjure up novel hypothetical particles and argue that if it were correct, the new species' giant footprints would already have shown up on Earth.

Since the 1930s, researchers have suggested that an unseen form of matter, dubbed dark matter, is the gravitational glue that keeps big cosmic structures like galaxies and galaxy clusters from flying apart (http://www.cfhtlens.org/public/what-dark-matter). This cosmic adhesive seems to outweigh the familiar stuff we see around us by a factor of 5.5 (http://sci.esa.int/planck/51557-planck-new-cosmic-recipe/), but its identity remains a stubborn mystery.

The leading suspect is a class of particles called WIMPs, or weakly interacting massive particles. Lying beyond physicists' best theory of particles, the standard model (http://home.web.cern.ch/about/physics/standard-model), WIMPs are beloved because they may solve other problems besides dark matter. Most notably, some of them arise in versions of a popular but unproven theory known as supersymmetry, which can explain the mass of the Higgs boson, which many physicists consider to be puzzlingly low.

Unfortunately, attempts to detect WIMPs have so far come up empty-handed. Unequivocal signs of the particles have not turned up in underground detectors (http://cdms.berkeley.edu/Education/DMpages/science/directDetection.shtml) designed to catch their occasional collisions with ordinary matter. And no supersymmetric particles have yet been produced at the world's most powerful particle smasher, the Large Hadron Collider, even though some versions of the theory predicted they should have been. "The LHC is making us realize that maybe supersymmetry may not be correct," says Peter Graham (https://physics.stanford.edu/people/faculty/peter-graham), a dark matter theorist at Stanford University in California. "That's led to a lot of interesting work thinking about new, different kinds of dark matter candidates."

One of these posits that dark matter may be made of hordes of subatomic particles called quarks, the lightest types of which form the garden-variety building blocks of protons and neutrons. The idea, which was first put forward (http://journals.aps.org/prd/abstract/10.1103/PhysRevD.30.272) by physicist Edward Witten (http://www.sns.ias.edu/witten) in 1984, is "appealing because it could mean that dark matter is a standard model phenomenon," says David Jacobs of the University of Cape Town in South Africa. Perhaps, he and his collaborators argue, quarks glommed together in huge numbers in the early universe, rather than only in the cliques of three most commonly seen in matter today. Or perhaps quarks still formed triplets (http://arxiv.org/abs/1005.2124), known as baryons, but those baryons then stuck together in enormous numbers—swarms of 10 trillion trillion or more. (The largest grouping of baryons known today hosts just 294 (http://education.jlab.org/itselemental/ele118.html).) Either way, this type of matter may have included so many quarks that it could be seen with the naked eye, forming chunks weighing at least as much as half a stick of butter. Witten called these lumps "quark nuggets."

In light of the so-far fruitless searches for WIMPs, Jacobs and his collaborators have revisited (http://mnras.oxfordjournals.org/content/450/4/3418.abstract) Witten's notion that these nuggets could form dark matter. The nuggets are one possibility for dark matter made of hefty lumps that the team calls "macros."

"I like that they're [thinking] out of the box," says dark matter theorist Jonathan Feng (http://www.ps.uci.edu/~jlf/) of the University of California, Irvine. That said, he believes it's too soon to count WIMPs out just because neither they nor their supersymmetric brethren have been detected in the first three years of operations at the LHC. "Rumors of the death of WIMPs are greatly exaggerated," Feng quips, adding that the particles' health would be of greater concern if they were still no-shows after another decade of observations at the LHC.

"It's long past time we consider things that are a little bit more complicated than just the simple WIMP," agrees Graham. But he disagrees with the team's notion that dark matter made of known quarks would be more theoretically attractive than that made of as-yet-undetected WIMPs, since it is far from clear whether quarks could form huge agglomerations.

Macro researchers acknowledge the point. Calculating the forces between quarks is notoriously difficult, and it is currently impossible to work out whether quarks could join up in such large throngs. And even if they did, it's not clear whether they would have been able to live through the searing heat of the early universe to tell their tale today, or whether they may have come together only briefly and then dispersed, like a flash mob. "We don't know whether this stuff … will be stable," says macro proponent Glenn Starkman (http://www.phys.cwru.edu/faculty/?starkman) of Case Western Reserve University in Cleveland, Ohio.

Still, the possibility can't be ruled out, and Starkman and others say researchers should go look for signs of macros. The team calculates that those weighing between about 50 and 100 million billion (10^17) grams could account for dark matter. If its constituent particles were packed as tightly as those inside an atomic nucleus, a macro weighing a billion grams, or 1,000 tonnes, would measure about 30 centimeters across. "It would look like a rock or a bowling ball—until you tried to pick it up," says Starkman.

Celestial surveys would have missed macros because they are relatively few and far between and, compared with other astronomical bodies, puny. But they should occasionally cross paths with Earth and could leave telltale signatures when they hit the atmosphere or surface, Starkman says. Ground-based detectors that search the atmosphere for signs of impacting space particles called cosmic rays, for example, might be able to catch macros hurtling along too, he suggested earlier this month. But after a subsequent meeting with members of the largest cosmic-ray observatory (https://www.auger.org/index.php/gallery/videos) in the world, an array of detectors in Argentina called the Pierre Auger Observatory, that possibility looks less promising. That's because the Auger plucks out only the fastest-moving signals from the stream of incoming data. "[Macros] move very much slower (about 1,000 times) than a typical cosmic ray, and at present Auger appears not able to see such things," says Jacobs.

Traveling at that speed— estimated at 300 kilometers/second—macros should have stuck out like sore thumbs in meteor observations if they were actually pummeling the Earth, says Peter Jenniskens (http://www.seti.org/users/peter-jenniskens), a meteor researcher at the SETI Institute in Mountain View, California. The fastest meteors, the Leonids (http://leonid.arc.nasa.gov/history.html), slice through the atmosphere at about 70 kilometers per second, so "anything streaking into the atmosphere at 300 kilometers per second would certainly have been noticed" by naked-eye observers and in photographs, agrees Jay Melosh (http://www.eaps.purdue.edu/people/faculty-pages/melosh.html), a planetary scientist at Purdue University in West Lafayette, Indiana.

Starkman estimates that a bowling-ball-sized macro should hit the Earth once a year. But such an object would deposit about half the energy of the atomic bomb that leveled Hiroshima into the atmosphere, says Melosh. "Such a large energy release would certainly have been noted any time after 1960 when [a worldwide network] was put in place to detect just such events," he says. Though the network has registered several events above that energy (https://en.wikipedia.org/wiki/Chelyabinsk_meteor), Melosh does not think any were unusual enough to represent an "exotic bowling ball." Moreover, he says, such an object "would have had the momentum to punch entirely through the Earth and emerge at nearly the same velocity on the other side," releasing as much energy as a magnitude 10 earthquake. "Again, hardly something to be missed," he says.

Whether or not the macro dark matter hypothesis, in some form, can survive such criticisms is unclear, but Feng says it's worth studying. "It does have the advantage of being a testable idea with real-world consequences," he says. "It's going to spur a lot of interesting discussions."

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Backreaction: Macro Dark Matter (http://backreaction.blogspot.com/2015/09/macro-dark-matter.html)
Theoretical physicist and blogger Sabine Hossenfelder explains why she "hates" the idea of macro dark matter—but thinks the idea is still important to pursue.

The Nature of Reality: Journey Into the Dark Realm (http://www.pbs.org/wgbh/nova/blogs/physics/2014/01/journey-into-the-dark-realm/)
What if dark matter isn't just one particle, but a diverse realm of dark matter particles that experience forces that don't affect ordinary matter? Don Lincoln explores the "dark realm."

NOVA scienceNOW: Dark Matter (http://www.pbs.org/wgbh/nova/physics/dark-matter.html) (Video)
Host Neil deGrasse Tyson reports from a half mile underground in an abandoned mine, where scientists are using special detectors to look for evidence of a ghostly substance that they believe makes up most of the matter of the universe—a hypothetical entity called dark matter.

Maggie McKee

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