

Solving the Dark Energy Mystery

Forty-five years ago this month, a telescope tucked inside a 14-story, 500-ton dome atop a mile-high peak in Arizona took in the night sky for the first time and recorded its observations in glass photographic plates. [23]

The PRISMA researchers propose a scenario in which two dark matter particles collide, resulting in their mutual annihilation. [21]

A new model introduces a charge for dark matter, which would allow it to radiate energy and form compact objects such as dark stars or dark galaxies. [20]

Just how quickly is the dark matter near Earth zipping around? The speed of dark matter has far-reaching consequences for modern astrophysical research, but this fundamental property has eluded researchers for years. [19]

A NASA rocket experiment could use the Doppler effect to look for signs of dark matter in mysterious X-ray emissions from space. [18]

CfA astronomers Annalisa Pillepich and Lars Hernquist and their colleagues compared gravitationally distorted Hubble images of the galaxy cluster Abell 2744 and two other clusters with the results of computer simulations of dark matter haloes. [17]

In a paper published July 20 in the journal Physical Review Letters, an international team of cosmologists uses data from the intergalactic medium—the vast, largely empty space between galaxies—to narrow down what dark matter could be. [16]

But a new hypothesis might have gotten us closer to figuring out its identity, because physicists now suspect that dark matter has been changing forms this whole time - from ghostly particles in the Universe's biggest structures, to a strange, superfluid state at smaller scales. And we might soon have the tools to confirm it. [15]

Superfluids may exist inside neutron stars, and some researchers have speculated that space-time itself may be a superfluid. So why shouldn't dark matter have a superfluid phase, too? [14]

"The best result on dark matter so far—and we just got started." This is how scientists behind XENON1T, now the most sensitive dark matter experiment world-wide, commented on their first result from a short 30-day run presented today to the scientific community. [13]

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

SIMPs would resolve certain discrepancies between simulations of the distribution of dark matter, like this one, and the observed properties of the galaxies.

In particle physics and astrophysics, weakly interacting massive particles, or WIMPs, are among the leading hypothetical particle physics candidates for dark matter.

Contents

The Big Bang.....	3
Solving the dark energy mystery: A new assignment for a 45-year-old telescope	4
Do massive dark matter "nuggets" lurk in our galaxy?	7
Dark matter uncovered	8
New theory of dark matter based on the detection of unusual X-ray radiation from galaxies	10
X-ray radiation produced by the annihilation of dark matter.....	10
Synopsis: A Way to Cool Dark Matter.....	11
Chasing dark matter with the oldest stars in the Milky Way	12
Why it matters	13
A speed trap for dark matter, revisited.....	14
Mapping dark matter	15
Dark matter is likely 'cold,' not 'fuzzy,' scientists report after new simulations	16
This New Explanation For Dark Matter Could Be The Best One Yet.....	18
Dark Matter Recipe Calls for One Part Superfluid	20
Impossible Superfluids.....	21
XENON1T, the most sensitive detector on Earth searching for WIMP dark matter, releases its first result	21

Out with the WIMPs, in with the SIMPs?.....	22
Dark matter composition research - WIMP	23
Weakly interacting massive particles	24
Evidence for an accelerating universe	24
Equation	25
Explanatory models	26
Dark Matter and Energy	26
Cosmic microwave background.....	26
Thermal radiation	26
Electromagnetic Field and Quantum Theory	27
Lorentz transformation of the Special Relativity	28
The Classical Relativistic effect.....	28
Electromagnetic inertia and Gravitational attraction	28
Electromagnetic inertia and mass.....	29
Electromagnetic Induction	29
Relativistic change of mass	29
The frequency dependence of mass	29
Electron – Proton mass rate	29
Gravity from the point of view of quantum physics	30
The Gravitational force.....	30
The Graviton	30
Conclusions.....	30
References	31

Author: George Rajna

The Big Bang

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

Solving the dark energy mystery: A new assignment for a 45-year-old telescope

Forty-five years ago this month, a telescope tucked inside a 14-story, 500-ton dome atop a mile-high peak in Arizona took in the night sky for the first time and recorded its observations in glass photographic plates.

Today, the dome closes on the previous science chapters of the 4-meter Nicholas U. Mayall Telescope so that it can prepare for its new role in creating the largest 3-D map of the universe. This map could help to solve the mystery of dark energy, which is driving the accelerating expansion of the universe.

The temporary closure sets in motion the largest overhaul in the telescope's history and sets the stage for the installation of the Dark Energy Spectroscopic Instrument (DESI), which will begin a five-year observing run next year at the National Science Foundation's Kitt Peak National Observatory (KPNO) - part of the National Optical Astronomy Observatory (NOAO).

"This day marks an enormous milestone for us," said DESI Director Michael Levi of the Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab), which is leading the project's international collaboration. "Now we remove the old equipment and start the yearlong process of putting the new stuff on." More than 465 researchers from about 71 institutions are participating in the DESI collaboration.

The entire top end of the telescope, which weighs as much as a school bus and houses the telescope's secondary mirror and a large digital camera, will be removed and replaced with DESI instruments. A large crane will lift the telescope's top end through the observing slit in its dome.

Besides providing new insights about the universe's expansion and large-scale structure, DESI will also help to set limits on theories related to gravity and the formative stages of the universe, and could even provide new mass measurements for a variety of elusive yet abundant subatomic particles called neutrinos.

"One of the primary ways that we learn about the unseen universe is by its subtle effects on the clustering of galaxies," said DESI Collaboration Co-Spokesperson Daniel Eisenstein of Harvard University. "The new maps from DESI will provide an exquisite new level of sensitivity in our study of cosmology."

The Mayall Telescope has played an important role in many astronomical discoveries, including measurements supporting the discovery of dark energy and establishing the role of dark matter in the universe from measurements of galaxy rotation. Its observations have also been used in determining the scale and structure of the universe. Dark matter and dark energy together are believed to make up about 95 percent of all of the universe's mass and energy.

It was one of the world's largest optical telescopes at the time it was built, and because of its sturdy construction it is perfectly suited to carry the new 9-ton instrument.

"We started this project by surveying large telescopes to find one that had a suitable mirror and wouldn't collapse under the weight of such a massive instrument," said Berkeley Lab's David Schlegel, a DESI project scientist.

Arjun Dey, the NOAO project scientist for DESI, explained, "The Mayall was precociously engineered like a battleship and designed with a wide field of view."

The expansion of the telescope's field-of-view will allow DESI to map out about one-third of the sky.

Brenna Flaugher, a DESI project scientist who leads the Astrophysics Department at Fermi National Accelerator Laboratory, said DESI will transform the speed of science at the Mayall Telescope.

"The telescope was designed to carry a person at the top who aimed and steered it, but with DESI it's all automated," she said. "Instead of one at a time we can measure the velocities of 5,000 galaxies at a time - we will measure more than 30 million of them in our five-year survey."

DESI will use an array of 5,000 swiveling robots, each carefully choreographed to point a fiber-optic cable at a preprogrammed sequence of deep-space objects, including millions of galaxies and quasars, which are galaxies that harbor massive, actively feeding black holes.

The fiber-optic cables will carry the light from these objects to 10 spectrographs, which are tools that will measure the properties of this light and help to pinpoint the objects' distance and the rate at which they are moving away from us. DESI's observations will provide a deep look into the early universe, up to about 11 billion years ago.

The cylindrical, fiber-toting robots, which will be embedded in a rounded metal unit called a focal plane, will reposition to capture a new exposure of the sky roughly every 20 minutes. The focal plane, which is now being assembled at Berkeley Lab, is expected to be completed and delivered to Kitt Peak this year.

DESI will scan one-third of the sky and will capture about 10 times more data than a predecessor survey, the Baryon Oscillation Spectroscopic Survey (BOSS). That project relied on a manually rotated sequence of metal plates - with fibers plugged by hand into pre-drilled holes - to target objects.



The first of 10 wedge-shaped petals for the DESI project is fully stocked with 500 slender robotic positioners. These positioners will each swivel independently to gather light from a preprogrammed sequence of space objects, including [...more](#)

All of DESI's six lenses, each about a meter in diameter, are complete. They will be carefully stacked and aligned in a steel support structure and will ultimately ride with the focal plane atop the telescope.

Each of these lenses took shape from large blocks of glass. They have criss-crossed the globe to receive various treatments, including grinding, polishing, and coatings. It took about 3.5 years to produce each of the lenses, which now reside at University College London in the U.K. and will be shipped to the DESI site this spring.

The Mayall Telescope has most recently been enlisted in a DESI-supporting sky survey known as the Mayall z-Band Legacy Survey (MzLS), which is one of four sky surveys that DESI will use to preselect its targeted sky objects. That survey wrapped up just days before the Mayall's temporary closure, while the others are ongoing.

Data from these surveys are analyzed at Berkeley Lab's National Energy Research Scientific Computing Center (NERSC), a DOE Office of Science User Facility. Data from these surveys have been released to the public at legacysurvey.org.

"We can see about a billion galaxies in the survey images, which is quite a bit of fun to explore," Schlegel said. "The DESI instrument will precisely measure millions of those galaxies to see the effects of dark energy."

Levi noted that there is already a lot of computing work underway at NERSC to prepare for the stream of data that will pour out of DESI once it starts up.

"This project is all about generating huge quantities of data," Levi said. "The data will go directly from the telescope to NERSC for processing. We will create hundreds of universes in these computers and see which universe best fits our data."

Installation of DESI's components is expected to begin soon and to wrap up in April 2019, with first science observations planned in September 2019.

"Installing DESI on the Mayall will put the telescope at the heart of the next decade of discoveries in cosmology," said Risa Wechsler, DESI Collaboration Co-Spokesperson and associate professor of physics and astrophysics at SLAC National Accelerator Laboratory and Stanford University. "The amazing 3-D map it will measure may solve some of the biggest outstanding questions in cosmology, or surprise us and bring up new ones." [23]

Do massive dark matter "nuggets" lurk in our galaxy?

When astrophysicists talk about [dark matter](#) - a mysterious substance that comprises 80% of the universe's total mass - they are generally thinking in terms of vast clouds of particles extending like halos from the normal matter concentrated at the heart of galaxies.

But does dark matter exist solely in this tenuous form, or can it condense into denser structures, analogous to those formed by normal matter?

Matthew Buckley, a theoretical astrophysicist at Rutgers University in New Brunswick, New Jersey, US, thinks such structures are theoretically possible. Within the next few years, he suggests, it might even be possible to detect them in our own galaxy via their gravitational effects.

Not that he's going so far as to say there might be dark-matter planets, suns, or even people - fascinating as that might be to a science fiction fan. What he's looking for are larger structures, with masses of one million to 100 million times that of the sun. (Since our galaxy contains about a trillion suns worth of dark matter, there could easily be many of these objects around ... if they exist at all.)

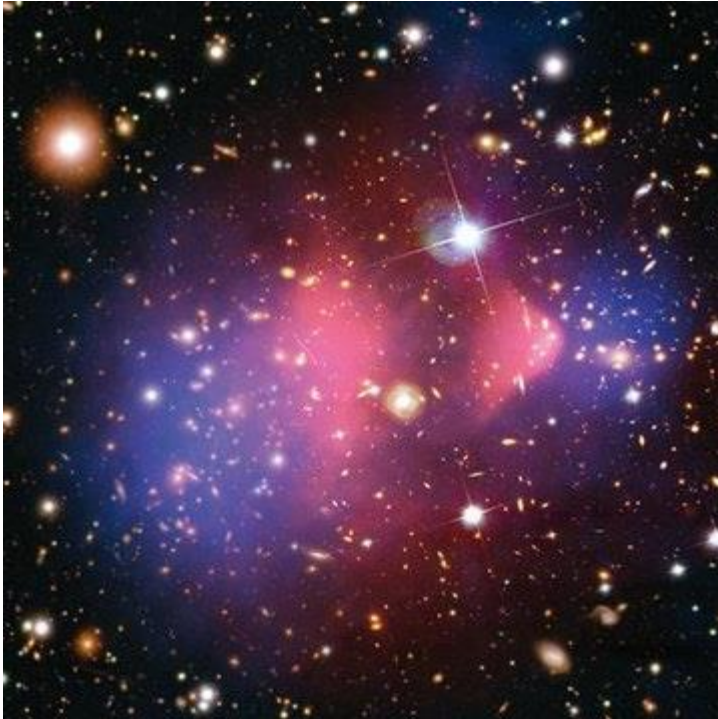
On first impression, it seems an obvious idea. After all, if normal matter can condense into the gas and dust clouds that eventually form into planets, moons, suns, rocks, poodles, and people, why can't dark matter do the same?

It turns out not to be as simple as that, Buckley says. For dark matter to condense in this manner, he says, there has to be a way for the particles to lose energy, or "cool", as they fall toward each

other. Otherwise, they just whizz past too quickly to clump together and head off on their own ways again, like ships in the night.

For ordinary matter, Buckley says, the thing that slows them down is the emission of electromagnetic radiation. This bleeds off energy, gradually slowing the particles' motion by enough to allow them to clump together.

Initially, Buckley says, he thought this was impossible for dark matter, but in [a 2009 paper in the journal *Physical Review D*](#), he was part of team that calculated the theoretical feasibility of "dark radiation" that would serve the same function for dark matter.



Dark matter uncovered

But scientists know that the giant dark matter halos surrounding large galaxies can't collapse in this matter. If they could, they would have done so long ago and would no longer exist.

Buckley's newest realisation, described in [a paper currently posted on the pre-print server arXiv](#), was that this didn't mean smaller blobs of dark matter couldn't condense. "If you fiddle with the parameters," he says, "you can make it so smaller halos cool and big ones don't."

What this means is that there might be "nuggets" of dark matter floating through a haze of dark matter - not just in the dark matter halo, but within the portions of the galaxy where we live.

How large these "nuggets" might be is an open question, based on such key factors as the masses of the dark-matter equivalents of electrons and protons, and the strength of their interaction with

dark radiation. But by fiddling with these parameters, Buckley says, it's possible to create a model in which million-stellar-mass blobs of dark matter condense, while the sprawling trillion-solar-mass halo of the entire galaxy does not.

Buckley notes that to date, his dark matter model is very simple - far less complex than our understanding of normal matter's sub-atomic world.

"It's fun to build really complicated models," he says, "but until I have a hint that this is how dark matter works, then spending time writing increasingly baroque models for it is maybe not the best use of my time."

He also chose parameters to produce objects in the size range of 100 million solar masses to one million solar masses. In this case, the reason is simple: that's a size range in which their gravitational effects should soon be detectable with [the European Space Agency's Gaia space telescope](#).

That telescope is currently in the process of a five to nine year mission to monitor the movements of a billion stars. Once the data is in, one of the things it should be able to show are loosely paired binary stars: pairs that orbit each other but are so far apart that the gravitational forces between them are barely strong enough to hold them together.

If dark matter objects of the size Buckley is looking for exist, they would have enough gravity that chance encounters with them should long ago have yanked apart most of these loose binaries. Thus, by looking at how many loose binary pairs exist, he says, it should be possible to put an upper bound on the number of dark matter objects roaming the galaxy.

Did dinosaurs fall foul of dark matter?

Even if such objects prove not to exist, he says, it would be a useful find because it would rule out one form that dark matter could take.

"We've known about dark matter for a long time," Buckley says, but "we still don't really know what it is.

"I wrote down this model. I don't know whether it's true or false, but I believe I will be able to answer that question in the near future."

Brad Tucker, an astrophysicist-cosmologist at Australian National University who was not part of Buckley's study team, is impressed.

"I like this paper," he says. "It's particularly interesting that this was done with a 'vanilla/basic' model of dark matter particle physics."

With a more complex model, he says, "you can get even smaller or different effects."

He also agrees that Gaia is a perfect instrument for testing the theory. The best way to detect such dark matter objects he says, "is to see how they gravitationally influence small-scale objects such clusters, stars, and so on".

"The precision of Gaia means now this is possible," he adds. [22]

New theory of dark matter based on the detection of unusual X-ray radiation from galaxies

Dark matter is increasingly puzzling. Around the world, physicists have been trying for decades to determine the nature of these matter particles, which do not emit light and are therefore invisible to the human eye. Their existence was postulated in the 1930s to explain certain astronomical observations. As visible matter, like the one that makes up the stars and the Earth, constitutes just 5 percent of the universe, it has been proposed that dark matter must represent 23 percent of what is out there. But to date and despite intensive research, it has proved impossible to actually identify the particles involved. Researchers at Johannes Gutenberg University Mainz (JGU) have now presented a novel theory of dark matter, which implies that dark matter particles may be very different from what is normally assumed. In particular, their theory involves dark matter particles which are extremely light—almost one hundred times lighter than electrons, in stark contrast to many conventional models that involve very heavy dark matter particles instead.

According to common theory, dark matter must exist because otherwise stars would not continue to rotate around the center of their galaxies as they in fact do. Among the particularly favored candidates for dark matter are so-called weakly interacting massive particles, or WIMPs. Researchers are searching for these in the Italian Gran Sasso underground laboratory, for example. But recent scientific publications in the field of astroparticle physics are increasingly taking the view that WIMPs are unlikely to be viable prospects when it comes to dark matter. "We, too, are currently actively on the search for possible alternatives," said Professor Joachim Kopp of Mainz University.

The physicist, together with his colleagues Vedran Brdar, Jia Liu, and Xiao-Ping Want, took a closer look at the results of observations undertaken by several independent groups in 2014. The groups reported the presence of a previously undetected spectral line, with an energy of 3.5 kiloelectron volts (keV), in x-ray light from distant galaxies and galaxy clusters. This unusual x-ray radiation might offer a clue to the nature of dark matter. It has been previously pointed out that dark matter particles might decay, thereby emitting x-rays. However, Joachim Kopp's team at the Mainz-based Cluster of Excellence on Precision Physics, Fundamental Interactions and Structure of Matter (PRISMA) is taking another approach.

X-ray radiation produced by the annihilation of dark matter

The PRISMA researchers propose a scenario in which two dark matter particles collide, resulting in their mutual annihilation. This is analogous to what happens, for instance, when an electron meets with its antiparticle, a positron. "It has long been assumed that it would not be possible to observe such annihilation of dark matter if it were made of particles that light," explained Kopp. "We have

subjected our new model to scrutiny and have compared it with experimental data, and it all fits together much better than in the case of older models."

According to Kopp's model, [dark matter particles](#) would be fermions with a mass of only a few kiloelectron volts, frequently called sterile neutrinos. Such lightweight dark matter is usually considered problematic because it makes it difficult to explain how galaxies could have been formed. "So far, we have been able to deal with these concerns," explained Kopp. "Our model provides an elegant way out." The supposition that the annihilation of dark matter is a two-step process is of crucial importance in this context: during the initial stage of the process, an intermediate state is formed, which later disintegrates into the observed x-ray photons. "The results of our calculations show that the resulting x-ray signature correlates closely with the observations and thus offers a novel explanation for these," added Kopp.

At the same time, the new [model](#) itself is so general that it will offer an interesting starting point for the search for dark [matter](#) even if it turns out that the [spectral line](#) discovered in 2014 has a different origin. Theoretical and experimental physicists at JGU are currently working on the proposed ESA mission e-ASTROGRAM, which aims at analyzing astrophysical [x-ray radiation](#) with previously unachieved accuracy. [21]

Synopsis: A Way to Cool Dark Matter

One widely held belief about dark matter is that it cannot cool off by radiating energy. If it could, then it might bunch together and create compact objects in the same way that baryonic matter forms planets, stars, and galaxies. Observations so far suggest that dark matter doesn't do that—it resides only in diffuse halos that encompass galaxies. But what if galaxies do contain condensed nuggets of dark matter, and we just haven't found them yet? Matthew Buckley and Anthony DiFranzo, both of Rutgers University, New Jersey, propose a new model for dark matter that allows it to cool. While their model permits most of the dark matter in a galaxy to form a halo, it also foresees thousands of dark matter substructures sprinkled throughout the galaxy.

The cooling of baryonic matter that led to the formation of cosmic structures was primarily due to interactions between charged particles. If dark matter contains particles that carry something analogous to a charge, perhaps it too could cool. Buckley and DiFranzo create a model where dark matter contains two types of charged particle—the shadowy equivalent of protons and electrons—and show that such particles could radiate energy. Other researchers have pondered dark matter cooling, but those efforts weren't able to explain why galactic halos don't collapse. The new model circumvents that problem: Above some critical mass for the dark matter content in a galaxy, cooling is hindered, and dark matter is stuck in a halo. Below that mass, a sufficiently dense blob of dark matter could clump together into a compact object.

The authors do not predict what these objects would be or how astronomers would find them. They speculate that, depending on certain model parameters, these dark denizens could range in mass from supermassive stars to dwarf galaxies. [20]

Chasing dark matter with the oldest stars in the Milky Way

Just how quickly is the dark matter near Earth zipping around? The speed of dark matter has far-reaching consequences for modern astrophysical research, but this fundamental property has eluded researchers for years.

In a paper published Jan. 22 in the journal *Physical Review Letters*, an international team of astrophysicists provided the first clue: The solution to this mystery, it turns out, lies among some of the oldest stars in the galaxy.

"Essentially, these old stars act as visible speedometers for the invisible dark matter, measuring its speed distribution near Earth," said Mariangela Lisanti, an assistant professor of physics at Princeton University. "You can think of the oldest stars as a luminous tracer for the dark matter. The dark matter itself we'll never see, because it's not emitting light to any observable degree—it's just invisible to us, which is why it's been so hard to say anything concrete about it."

In order to determine which stars behave like the invisible and undetectable dark matter particles, Lisanti and her colleagues turned to a computer simulation, Eris, which uses supercomputers to replicate the physics of the Milky Way galaxy, including dark matter.

"Our hypothesis was that there's some subset of stars that, for some reason, will match the movements of the dark matter," said Jonah Herzog-Arbeitman, an undergraduate and a co-author on the paper. His work with Lisanti and her colleagues the summer after his first year at Princeton turned into one of his junior papers and contributed to this journal article.

Herzog-Arbeitman and Lina Necib at the California Institute of Technology, another co-author on the paper, generated numerous plots from Eris data that compared various properties of dark matter to properties of different subsets of stars.

Their big breakthrough came when they compared the velocity of dark matter to that of stars with different "metallicities," or ratios of heavy metals to lighter elements.

The curve representing dark matter matched up beautifully with the stars that have the least heavy metals: "We saw everything line up," Lisanti said.

"It was one of those great examples of a pretty reasonable idea working pretty darn well," Herzog-Arbeitman said.

Astronomers have known for decades that metallicity can serve as a proxy for a star's age, since metals and other heavy elements are formed in supernovas and the mergers of neutron stars. The small galaxies that merged with the Milky Way typically have comparatively less of these heavy elements.

In retrospect, the correlation between dark matter and the oldest stars shouldn't be surprising, said Necib. "The dark matter and these old stars have the same initial conditions: they started in the same place and they have the same properties ... so at the end of the day, it makes sense that they're both acted on only through gravity," she said.

Why it matters

Since 2009, researchers have been trying to observe dark matter directly, by putting very dense material—often xenon—deep underground and waiting for the dark matter that flows through the planet to interact with it.

Lisanti compared these "direct detection" experiments to a game of billiards: "When a dark matter particle scatters off a nucleus in an atom, the collision is similar to two billiard balls hitting each other. If the [dark matter particle](#) is much less massive than the nucleus, then the nucleus won't move much after the collision, which makes it really hard to notice that anything happened."

That's why constraining the speed of dark matter is so important, she explained. If dark matter particles are both slow and light, they might not have enough kinetic energy to move the nuclear "billiard balls" at all, even if they smack right into one.

"But if the dark matter comes in moving faster, it's going to have more kinetic energy. That can increase the chance that in that collision, the recoil of the nucleus is going to be greater, so you'd be able to see it," Lisanti said.

Originally, scientists had expected to see enough particle interactions—enough moving billiard balls—to be able to derive the mass and velocity of the dark matter particles. But, Lisanti said, "we haven't seen anything yet."

So instead of using the interactions to determine the speed, researchers like Lisanti and her colleagues are hoping to flip the script, and use the speed to explain why the direct detection experiments haven't detected anything yet.

The failure—at least so far—of the direct detection experiments leads to two questions, Lisanti said. "How am I ever going to figure out what the speeds of these things are?" and "Have we not seen anything because there's something different in the speed distribution than we expected?"

Having a completely independent way to work out the speed of dark matter could help shed light on that, she said. But so far, it's only theoretical. Real-world astronomy hasn't caught up to the wealth of data produced by the Eris simulation, so Lisanti and her colleagues don't yet know how fast our galaxy's [oldest stars](#) are moving.

Fortunately, that information is being assembled right now by the European Space Agency's Gaia telescope, which has been scanning the Milky Way since July 2014. So far, information on only a small subset of stars has been released, but the full dataset will include far more data on nearly a billion [stars](#).

"The wealth of data on the horizon from current and upcoming stellar surveys will provide a unique opportunity to understand this [fundamental property](#) of dark matter," Lisanti said. [19]

A speed trap for dark matter, revisited

A NASA rocket experiment could use the Doppler effect to look for signs of dark matter in mysterious X-ray emissions from space.

Researchers who hoped to look for signs of dark matter particles in data from the Japanese ASTRO-H/Hitomi satellite suffered a setback last year when the satellite malfunctioned and died just a month after launch.

Now the idea may get a second chance.

In a new paper, published in *Physical Review D*, scientists from the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC), a joint institute of Stanford University and the Department of Energy's SLAC National Accelerator Laboratory, suggest that their novel search method could work just as well with the future NASA-funded Micro-X rocket experiment—an X-ray space telescope attached to a research rocket.

The search method looks for a difference in the Doppler shifts produced by movements of dark matter and regular matter, says Devon Powell, a graduate student at KIPAC and lead author on the paper with co-authors Ranjan Laha, Kenny Ng and Tom Abel.

The Doppler effect is a shift in the frequency of sound or light as its source moves toward or away from an observer. The rising and falling pitch of a passing train whistle is a familiar example, and the radar guns that cops use to catch speeders also work on this principle.

The dark matter search technique, called Dark Matter Velocity Spectroscopy, is like setting up a speed trap to “catch” dark matter.

“We think that dark matter has zero averaged velocity, while our solar system is moving,” says Laha, who is a postdoc at KIPAC. “Due to this relative motion, the dark matter signal would experience a Doppler shift. However, it would be completely different than the Doppler shifts from signals coming from astrophysical objects because those objects typically co-rotate around the center of the galaxy with the sun, and dark matter doesn't. This means we should be able to distinguish the Doppler signatures from dark and regular matter.”

Researchers would look for subtle frequency shifts in measurements of a mysterious X-ray emission. This 3500-electronvolt (3.5 keV) emission line, observed in data from the European XMM-Newton spacecraft and NASA's Chandra X-ray Observatory, is hard to explain with known astrophysical processes. Some say it could be a sign of hypothetical dark matter particles called sterile neutrinos decaying in space.

“The challenge is to find out whether the X-ray line is due to dark matter or other astrophysical sources,” Powell says. “We're looking for ways to tell the difference.”

The idea for this approach is not new: Laha and others described the method in a research paper last year, in which they suggested using X-ray data from Hitomi to do the Doppler shift comparison. Although the spacecraft sent some data home before it disintegrated, it did not see any sign of the 3.5-keV signal, casting doubt on the interpretation that it might be produced by the decay of dark

matter particles. The Dark Matter Velocity Spectroscopy method was never applied, and the issue was never settled.

In the future Micro-X experiment, a rocket will catapult a small telescope above Earth's atmosphere for about five minutes to collect X-ray signals from a specific direction in the sky. The experiment will then parachute back to the ground to be recovered. The researchers hope that Micro-X will do several flights to set up a speed trap for dark matter.

"We expect the energy shifts of dark matter signals to be very small because our solar system moves relatively slowly," Laha says. "That's why we need cutting-edge instruments with superb energy resolution. Our study shows that Dark Matter Velocity Spectroscopy could be successfully done with Micro-X, and we propose six different pointing directions away from the center of the Milky Way."

Esra Bulbul from the MIT Kavli Institute for Astrophysics and Space Research, who wasn't involved in the study, says, "In the absence of Hitomi observations, the technique outlined for Micro-X provides a promising alternative for testing the dark matter origin of the 3.5-keV line." But Bulbul, who was the lead author of the paper that first reported the mystery X-ray signal in superimposed data of 73 galaxy clusters, also points out that the Micro-X analysis would be limited to our own galaxy.

The feasibility study for Micro-X is more detailed than the prior analysis for Hitomi. "The earlier paper used certain approximations—for instance, that the dark matter halos of galaxies are spherical, which we know isn't true," Powell says. "This time we ran computer simulations without this approximation and predicted very precisely what Micro-X would actually see."

The authors say their method is not restricted to the 3.5-keV line and can be applied to any sharp signal potentially associated with dark matter. They hope that Micro-X will do the first practice test. Their wish might soon come true.

"We really like the idea presented in the paper," says Eneclali Figueroa-Feliciano, the principal investigator for Micro-X at Northwestern University, who was not involved in the study. "We would look at the center of the Milky Way first, where dark matter is most concentrated. If we saw an unidentified line and it were strong enough, looking for Doppler shifts away from the center would be the next step." [18]

Mapping dark matter

About eighty-five percent of the matter in the universe is in the form of dark matter, whose nature remains a mystery. The rest of the matter in the universe is of the kind found in atoms.

Astronomers studying the evolution of galaxies in the universe find that dark matter exhibits gravity and, because it is so abundant, it dominates the formation of large-scale structures in the universe like clusters of galaxies. Dark matter is hard to observe directly, needless to say, and it shows no evidence of interacting with itself or other matter other than via gravity, but fortunately it can be traced by modeling sensitive observations of the distributions of galaxies across a range of scales.

Galaxies generally reside at the centers of vast clumps of dark matter called haloes because they surround the clusters of galaxies. Gravitational lensing of more distant galaxies by dark matter haloes offers a particularly unique and powerful probe of the detailed distribution of dark matter. So-called strong gravitational lensing creates highly distorted, magnified and occasionally multiple images of a single source; so-called weak lensing results in modestly yet systematically deformed shapes of background galaxies that can also provide robust constraints on the distribution of dark matter within the clusters.

CfA astronomers Annalisa Pillepich and Lars Hernquist and their colleagues compared gravitationally distorted Hubble images of the galaxy cluster Abell 2744 and two other clusters with the results of computer simulations of dark matter haloes. They found, in agreement with key predictions in the conventional dark matter picture, that the detailed galaxy substructures depend on the dark matter halo distribution, and that the total mass and the light trace each other. They also found a few discrepancies: the radial distribution of the dark matter is different from that predicted by the simulations, and the effects of tidal stripping and friction in galaxies are smaller than expected, but they suggest these issues might be resolved with more precise simulations. Overall, however, the standard model of dark matter does an excellent and reassuring job of describing galaxy clustering. [17]

Dark matter is likely 'cold,' not 'fuzzy,' scientists report after new simulations

Dark matter is the aptly named unseen material that makes up the bulk of matter in our universe. But what dark matter is made of is a matter of debate.

Scientists have never directly detected dark matter. But over decades, they have proposed a variety of theories about what type of material—from new particles to primordial black holes—could comprise dark matter and explain its many effects on normal matter. In a paper published July 20 in the journal *Physical Review Letters*, an international team of cosmologists uses data from the intergalactic medium—the vast, largely empty space between galaxies—to narrow down what dark matter could be.

The team's findings cast doubt on a relatively new theory called "fuzzy dark matter," and instead lend credence to a different model called "cold dark matter." Their results could inform ongoing efforts to detect dark matter directly, especially if researchers have a clear idea of what sorts of properties they should be seeking.

"For decades, theoretical physicists have tried to understand the properties of the particles and forces that must make up dark matter," said lead author Vid Iršič, a postdoctoral researcher in the Department of Astronomy at the University of Washington. "What we have done is place constraints on what dark matter could be—and 'fuzzy dark matter,' if it were to make up all of dark matter, is not consistent with our data."

Scientists had drawn up both the "fuzzy" and "cold" dark-matter theories to explain the effects that dark matter appears to have on galaxies and the intergalactic medium between them.

Cold dark matter is the older of these two theories, dating back to the 1980s, and is currently the standard model for dark matter. It posits that dark matter is made up of a relatively massive,

slowmoving type of particle with "weakly interacting" properties. It helps explain the unique, large-scale structure of the universe, such as why galaxies tend to cluster in larger groups.

But the cold dark matter theory also has some drawbacks and inconsistencies. For example, it predicts that our own Milky Way Galaxy should have hundreds of satellite galaxies nearby. Instead, we have only a few dozen small, close neighbors.

The newer fuzzy dark matter theory addressed the deficiencies of the cold dark matter model. According to this theory, dark matter consists of an ultralight particle, rather than a heavy one, and also has a unique feature related to quantum mechanics. For many of the fundamental particles in our universe, their large-scale movements—traveling distances of meters, miles and beyond—can be explained using the principles of "classic" Newtonian physics. Explaining small-scale movements, such as at the subatomic level, requires the complex and often contradictory principles of quantum mechanics. But for the ultralight particle predicted in the fuzzy dark matter theory, movements at incredibly large scales—such as from one end of a galaxy to the other—also require quantum mechanics.

With these two theories of dark matter in mind, Iršic and his colleagues set out to model the hypothetical properties of dark matter based on relatively new observations of the intergalactic medium, or IGM. The IGM consists largely of dark matter—whatever that may be—along with hydrogen gas and a small amount of helium. The hydrogen within IGM absorbs light emitted from distant, bright objects, and astronomers have studied this absorption for decades using Earth-based instruments.

The team looked at how the IGM interacted with light emitted by quasars, which are distant, massive, starlike objects. One set of data came from a survey of 100 quasars by the European Southern Observatory in Chile. The team also included observations of 25 quasars by the Las Campanas Observatory in Chile and the W.M. Keck Observatory in Hawaii.

Using a supercomputer at the University of Cambridge, Iršic and co-authors simulated the IGM—and calculated what type of dark matter particle would be consistent with the quasar data. They discovered that a typical particle predicted by the fuzzy dark matter theory is simply too light to account for the hydrogen absorption patterns in the IGM. A heavier particle—similar to predictions of the traditional cold dark matter theory—is more consistent with their simulations.

"The mass of this particle has to be larger than what people had originally expected, based on the fuzzy dark matter solutions for issues surrounding our galaxy and others," said Iršic.

An ultralight "fuzzy" particle could still exist. But it cannot explain why galactic clusters form, or other questions like the paucity of satellite galaxies around the Milky Way, said Iršic. A heavier "cold" particle remains consistent with the astronomical observations and simulations of the IGM, he added.

The team's results do not address all of the longstanding drawbacks of the cold dark matter model. But Iršic believes that further mining of data from the IGM can help resolve the type—or types—of particles that make up dark matter. In addition, some scientists believe that there are no problems with the cold dark matter theory. Instead, scientists may simply not understand the complex forces at work in the IGM, Iršic added.

"Either way, the IGM remains a rich ground for understanding dark matter," said Iršic.

Co-authors on the paper are Matteo Viel of the International School for Advanced Studies in Italy, the Astronomical Observatory of Trieste and the National Institute for Nuclear Physics in Italy; Martin Haehnelt of the University of Cambridge; James Bolton of the University of Nottingham; and George Becker of the University of California, Riverside. The work was funded by the National Science Foundation, the National Institute for Nuclear Physics in Italy, the European Research Council, the National Institute for Astrophysics in Italy, the Royal Society in the United Kingdom and the Kavli Foundation. [16]

This New Explanation For Dark Matter Could Be The Best One Yet

It makes up about 85 percent of the total mass of the Universe, and yet, physicists still have no idea what dark matter actually is.

But a new hypothesis might have gotten us closer to figuring out its identity, because physicists now suspect that dark matter has been changing forms this whole time - from ghostly particles in the Universe's biggest structures, to a strange, superfluid state at smaller scales. And we might soon have the tools to confirm it.

Dark matter is a hypothetical substance that was proposed almost a century ago to account for the clear imbalance between the amount of matter in the Universe, and the amount of gravity that holds our galaxies together.

We can't directly detect dark matter, but we can see its effects on everything around us - the way galaxies rotate and the way light bends as it travels through the Universe suggests there's far more at play than we're able to pick up.

And now two physicists propose that dark matter has been changing the rules this whole time, and that could explain why it's been so elusive.

"It's a neat idea," particle physicist Tim Tait from the University of California, Irvine, who wasn't involved in the study, told Quanta Magazine.

"You get to have two different kinds of dark matter described by one thing."

The traditional view of dark matter is that it's made up of weakly interacting particles such as axions, which are influenced by the force of gravity in ways that we can observe at large scales.

This 'cold' form of dark matter can be used to predict how massive clusters of galaxies will behave, and fits into what we know about the 'cosmic web' of the Universe - scientists suggest that all galaxies are connected within a vast intergalactic web made up of invisible filaments of dark matter.

But when we scale down to individual galaxies and the way their stars rotate in relation to the galactic centre, something just doesn't add up.

"Most of the mass [in the Universe], which is dark matter, is segregated from where most of the ordinary matter lies," University of Pennsylvania physicist Justin Khoury explains in a press statement.

"On a cosmic web scale, this does well in fitting with the observations. On a galaxy cluster scale, it also does pretty well. However, when on the scale of galaxies, it does not fit."

Khoury and his colleague Lasha Berezhiani, now at Princeton University, suggest that the reason we can't reconcile dark matter's behaviour on both large and small scales in the Universe is because it can shift forms.

We've got the 'cold' dark matter particles for the massive galaxy clusters, but on a singular galactic scale, they suggest that dark matter takes on a superfluid state.

Superfluids are a form of cold, densely packed matter that has zero friction and viscosity, and can sometimes become a Bose-Einstein condensate, referred to as the 'fifth state of matter'.

And as strange as they sound, superfluids are starting to appear more accessible than ever before, with researchers announcing just last week that they were able to create light that acts like a liquid - a form of superfluid - at room temperature for the first time.

The more we come to understand superfluids, the more physicists are willing to entertain the idea that they could be far more common in the Universe than we thought.

"Recently, more physicists have warmed to the possibility of superfluid phases forming naturally in the extreme conditions of space," Jennifer Ouellette explains for Quanta Magazine.

"Superfluids may exist inside neutron stars, and some researchers have speculated that space-time itself may be a superfluid. So why shouldn't dark matter have a superfluid phase, too?"

The idea is that the 'halos' of dark matter that exist around individual galaxies create the conditions necessary to form a superfluid - the gravitational pull of the galaxy ensures that it's densely packed, and the coldness of space keeps the temperature suitably low.

Zoom out to a larger scale, and this gravitational pull becomes too weak to form a superfluid.

The key here is that the existence of superfluid dark matter could explain the strange behaviours of individual galaxies that gravity alone can't explain - it could be creating a second, as-yet-undefined force that acts just like gravity within the dark matter halos surrounding them.

As Ouellette explains, when you disturb an electric field, you get radio waves, and when you disturb a gravitational field, you get gravitational waves. When you disturb a superfluid? You get phonons (sound waves), and this extra force could work in addition to gravity.

"It's nice because you have an additional force on top of gravity, but it really is intrinsically linked to dark matter," Khoury told her. "It's a property of the dark matter medium that gives rise to this force."

We should be clear that this hypothesis is yet to be peer-reviewed, so this is all squarely in the realm of the hypothetical for now. But it's been published on the pre-print website arXiv.org for researchers in the field to pick over.

A big thing it has going for it is the fact that it could also explain 'modified Newtonian dynamics' (MOND) - a theory that says a modification of Newton's laws is needed to account for specific properties that have been observed within galaxies.

"In galaxies, there is superfluid movement of dark matter and MOND applies. However, in galaxy clusters, there is no superfluid movement of dark matter and MOND does not apply," the team suggests in a press statement.

We'll have to wait and see where this hypothesis goes, but the Khoury and Berezhiani say they're close to coming up with actual, testable ways that we can confirm their predictions based on superfluid dark matter.

And if their predictions bear out - we might finally be onto something when it comes to this massive cosmic mystery.

The research is available online at arXiv.org. [15]

Dark Matter Recipe Calls for One Part Superfluid

For years, dark matter has been behaving badly. The term was first invoked nearly 80 years ago by the astronomer Fritz Zwicky, who realized that some unseen gravitational force was needed to stop individual galaxies from escaping giant galaxy clusters. Later, Vera Rubin and Kent Ford used unseen dark matter to explain why galaxies themselves don't fly apart.

Yet even though we use the term "dark matter" to describe these two situations, it's not clear that the same kind of stuff is at work. The simplest and most popular model holds that dark matter is made of weakly interacting particles that move about slowly under the force of gravity. This so-called "cold" dark matter accurately describes large-scale structures like galaxy clusters. However, it doesn't do a great job at predicting the rotation curves of individual galaxies. Dark matter seems to act differently at this scale.

In the latest effort to resolve this conundrum, two physicists have proposed that dark matter is capable of changing phases at different size scales. Justin Khoury, a physicist at the University of Pennsylvania, and his former postdoc Lasha Berezhiani, who is now at Princeton University, say that in the cold, dense environment of the galactic halo, dark matter condenses into a superfluid — an exotic quantum state of matter that has zero viscosity. If dark matter forms a superfluid at the galactic scale, it could give rise to a new force that would account for the observations that don't fit the cold dark matter model. Yet at the scale of galaxy clusters, the special conditions required for a superfluid state to form don't exist; here, dark matter behaves like conventional cold dark matter.

"It's a neat idea," said Tim Tait, a particle physicist at the University of California, Irvine. "You get to have two different kinds of dark matter described by one thing." And that neat idea may soon be testable. Although other physicists have toyed with similar ideas, Khoury and Berezhiani are nearing the point where they can extract testable predictions that would allow astronomers to explore whether our galaxy is swimming in a superfluid sea.

Impossible Superfluids

Here on Earth, superfluids aren't exactly commonplace. But physicists have been cooking them up in their labs since 1938. Cool down particles to sufficiently low temperatures and their quantum nature will start to emerge. Their matter waves will spread out and overlap with one other, eventually coordinating themselves to behave as if they were one big "superatom." They will become coherent, much like the light particles in a laser all have the same energy and vibrate as one. These days even undergraduates create so-called Bose-Einstein condensates (BECs) in the lab, many of which can be classified as superfluids.

Superfluids don't exist in the everyday world — it's too warm for the necessary quantum effects to hold sway. Because of that, "probably ten years ago, people would have balked at this idea and just said 'this is impossible,'" said Tait. But recently, more physicists have warmed to the possibility of superfluid phases forming naturally in the extreme conditions of space. Superfluids may exist inside neutron stars, and some researchers have speculated that space-time itself may be a superfluid. So why shouldn't dark matter have a superfluid phase, too?

To make a superfluid out of a collection of particles, you need to do two things: Pack the particles together at very high densities and cool them down to extremely low temperatures. In the lab, physicists (or undergraduates) confine the particles in an electromagnetic trap, then zap them with lasers to remove the kinetic energy and lower the temperature to just above absolute zero. [14]

XENON1T, the most sensitive detector on Earth searching for WIMP dark matter, releases its first result

"The best result on dark matter so far—and we just got started." This is how scientists behind XENON1T, now the most sensitive dark matter experiment world-wide, commented on their first result from a short 30-day run presented today to the scientific community.

Dark matter is one of the basic constituents of the universe, five times more abundant than ordinary matter. Several astronomical measurements have corroborated the existence of dark matter, leading to a world-wide effort to observe dark matter particle interactions with ordinary matter in extremely sensitive detectors, which would confirm its existence and shed light on its properties. However, these interactions are so feeble that they have escaped direct detection up to this point, forcing scientists to build detectors that are increasingly sensitive. The XENON Collaboration, that with the XENON100 detector led the field for years in the past, is now back on the frontline with the XENON1T experiment. The result from a first short 30-day run shows that this detector has a new record low radioactivity level, many orders of magnitude below surrounding materials on Earth. With a total mass of about 3200kg, XENON1T is the largest detector of this type ever built. The combination of significantly increased size with much lower background implies excellent dark matter discovery potential in the years to come.

The XENON Collaboration consists of 135 researchers from the U.S., Germany, Italy, Switzerland, Portugal, France, the Netherlands, Israel, Sweden and the United Arab Emirates. The latest detector of the XENON family has been in science operation at the LNGS underground laboratory since autumn 2016. The only things you see when visiting the underground experimental site now

are a gigantic cylindrical metal tank filled with ultra-pure water to shield the detector at his center, and a three-story-tall, transparent building crowded with equipment to keep the detector running.

The XENON1T central detector, a so-called liquid xenon time projection chamber (LXeTPC), is not visible. It sits within a cryostat in the middle of the water tank, fully submersed in order to shield it as much as possible from natural radioactivity in the cavern. The cryostat keeps the xenon at a temperature of -95°C without freezing the surrounding water. The mountain above the laboratory further shields the detector, preventing perturbations by cosmic rays. But shielding from the outer world is not enough since all materials on Earth contain tiny traces of natural radioactivity. Thus, extreme care was taken to find, select and process the materials of the detector to achieve the lowest possible radioactive content. Laura Baudis, professor at the University of Zürich and professor Manfred Lindner from the Max-Planck-Institute for Nuclear Physics in Heidelberg, emphasize that this allowed XENON1T to achieve record "silence," which is necessary to listen for the very weak voice of dark matter.

A particle interaction in liquid xenon leads to tiny flashes of light. This is what the XENON scientists are recording and studying to infer the position and the energy of the interacting particle, and whether or not it might be dark matter. The spatial information allows the researchers to select interactions occurring in the one-ton central core of the detector.

XENON1T, the most sensitive detector on Earth searching for WIMP dark matter, releases its first result

The surrounding xenon further shields the core xenon target from all materials that already have tiny surviving radioactive contaminants. Despite the shortness of the 30-day science run, the sensitivity of XENON1T has already overcome that of any other experiment in the field, probing unexplored dark matter territory. "WIMPs did not show up in this first search with XENON1T, but we also did not expect them so soon," says Elena Aprile, Professor at Columbia University and spokesperson for the project. "The best news is that the experiment continues to accumulate excellent data, which will allow us to test quite soon the WIMP hypothesis in a region of mass and cross-section with normal atoms as never before. A new phase in the race to detect dark matter with ultra-low background massive detectors on Earth has just begun with XENON1T. We are proud to be at the forefront of the race with this amazing detector, the first of its kind." [13]

Out with the WIMPs, in with the SIMPs?

Like cops tracking the wrong person, physicists seeking to identify dark matter—the mysterious stuff whose gravity appears to bind the galaxies—may have been stalking the wrong particle. In fact, a particle with some properties opposite to those of physicists' current favorite dark matter candidate—the weakly interacting massive particle, or WIMP—would do just as good a job at explaining the stuff, a quartet of theorists says. Hypothetical strongly interacting massive particles— or SIMPs—would also better account for some astrophysical observations, they argue.

SIMPs can also provide just the right amount of dark matter, assuming the theorists add a couple of wrinkles. The SIMPs must disappear primarily through collisions in which three SIMPs go in and only two SIMPs come out. These events must be more common than ones in which two SIMPs annihilate each other to produce two ordinary particles. Moreover, the theorists argue, SIMPs

must interact with ordinary matter, although much more weakly than WIMPs. That's because the three-to-two collisions would heat up the SIMPs if they could not interact and share heat with ordinary matter.

Moreover, the fact that SIMPs must interact with ordinary matter guarantees that, in principle, they should be detectable in some way, Hochberg says. Whereas physicists are now searching for signs of WIMPs colliding with massive atomic nuclei, researchers would probably have to look for SIMPs smacking into lighter electrons because the bantamweight particles would not pack enough punch to send a nucleus flying.

Compared with WIMPy dark matter, SIMPy dark matter would also have another desirable property. As the universe evolved, dark matter coalesced into clumps, or halos, in which the galaxies then formed. But computer simulations suggest that dark matter that doesn't interact with itself would form myriad little clumps that are very dense in the center. And little "dwarf galaxies" aren't as abundant and the centers of galaxies aren't as dense as the simulations suggest. But strongly interacting dark matter would smooth out the distribution of dark matter and solve those problems, Hochberg says. "This isn't some independent thing that we've just forced into the model," she says. "It just naturally happens."

The new analysis "has the flavor of the WIMP miracle, which is nice," says Jonathan Feng, a theorist at UC Irvine who was not involved in the work. Feng says he's been working on similar ideas and that the ability to reconcile the differences between dark matter simulations and the observed properties of galaxies makes strongly interacting dark matter attractive conceptually.

However, he cautions, it may be possible that, feeble as they may be, the interactions between dark and ordinary matter might smooth out the dark matter distribution on their own. And Feng says he has some doubts about the claim that SIMPs must interact with ordinary matter strongly enough to be detected. So the SIMP probably won't knock WIMP off its perch as the best guess for the dark matter particle just yet, Feng says: "At the moment, it's not as well motivated as the WIMP, but it's definitely worth exploring." [12]

Dark matter composition research - WIMP

The WIMP (Weakly interactive massive particles) form a class of heavy particles, interacting slightly with matter, and constitute excellent candidates with the nonbaryonic dark matter. The neutralino postulated by the supersymmetric extensions of the standard model of particle physics. The idea of supersymmetry is to associate each boson to a fermion and vice versa. Each particle is then given a super-partner, having identical properties (mass, load), but with a spin which differs by $1/2$. Thus, the number of particles is doubled. For example, the photon is accompanied by a photino, the graviton by a gravitino, the electron of a selectron, etc. Following the impossibility to detect a 511 keV boson (the electron partner), the physicists had to re-examine the idea of an exact symmetry. Symmetry is 'broken' and superpartners have a very important mass. One of these superparticles called LSP (Lightest Supersymmetric Particle) is the lightest of all. In most of the supersymmetric theories (without violation of the R-parity) the LSP is a stable particle because it cannot disintegrate in a lighter element. It is of neutral color and electric charge and is then only sensitive

to weak interaction (weak nuclear force). It is then an excellent candidate for the not-baryonic dark matter. [11]

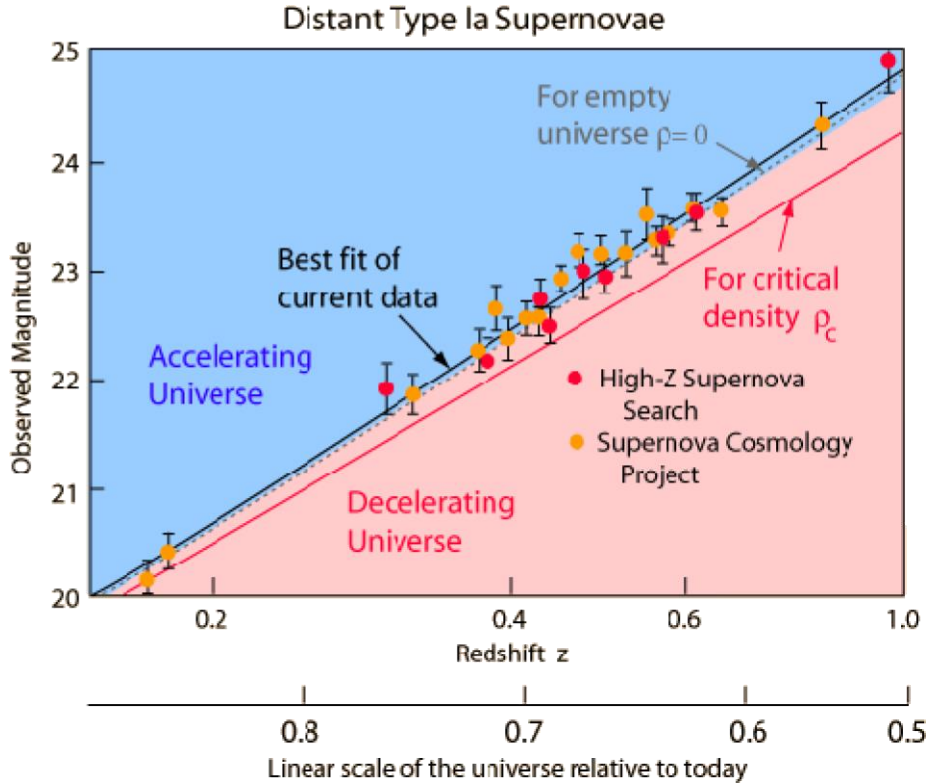
Weakly interacting massive particles

In particle physics and astrophysics, weakly interacting massive particles, or WIMPs, are among the leading hypothetical particle physics candidates for dark matter. The term "WIMP" is given to a dark matter particle that was produced by falling out of thermal equilibrium with the hot dense plasma of the early universe, although it is often used to refer to any dark matter candidate that interacts with standard particles via a force similar in strength to the weak nuclear force. Its name comes from the fact that obtaining the correct abundance of dark matter today via thermal production requires a self-annihilation cross section, which is roughly what is expected for a new particle in the 100 GeV mass range that interacts via the electroweak force. This apparent coincidence is known as the "WIMP miracle". Because supersymmetric extensions of the standard model of particle physics readily predict a new particle with these properties, a stable supersymmetric partner has long been a prime WIMP candidate. However, recent null results from direct detection experiments including LUX and SuperCDMS, along with the failure to produce evidence of supersymmetry in the Large Hadron Collider (LHC) experiment has cast doubt on the simplest WIMP hypothesis. Experimental efforts to detect WIMPs include the search for products of WIMP annihilation, including gamma rays, neutrinos and cosmic rays in nearby galaxies and galaxy clusters; direct detection experiments designed to measure the collision of WIMPs with nuclei in the laboratory, as well as attempts to directly produce WIMPs in colliders such as the LHC. [10]

Evidence for an accelerating universe

One of the observational foundations for the big bang model of cosmology was the observed expansion of the universe. [9] Measurement of the expansion rate is a critical part of the study, and it has been found that the expansion rate is very nearly "flat". That is, the universe is very close to the critical density, above which it would slow down and collapse inward toward a future "big crunch". One of the great challenges of astronomy and astrophysics is distance measurement over the vast distances of the universe. Since the 1990s it has become apparent that type Ia supernovae offer a unique opportunity for the consistent measurement of distance out to perhaps 1000 Mpc. Measurement at these great distances provided the first data to suggest that the expansion rate of the universe is actually accelerating. That acceleration implies an energy density that acts in opposition to gravity which would cause the expansion to accelerate. This is an energy density which we have not directly detected observationally and it has been given the name "dark energy".

The type Ia supernova evidence for an accelerated universe has been discussed by Perlmutter and the diagram below follows his illustration in Physics Today.



The data summarized in the illustration above involve the measurement of the redshifts of the distant supernovae. The observed magnitudes are plotted against the redshift parameter z . Note that there are a number of Type 1a supernovae around $z=0.6$, which with a Hubble constant of 71 km/s/mpc is a distance of about 5 billion light years.

Equation

The cosmological constant Λ appears in Einstein's field equation [5] in the form of

$$R_{\mu\nu} - \frac{1}{2}R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu},$$

where R and g describe the structure of spacetime, T pertains to matter and energy affecting that structure, and G and c are conversion factors that arise from using traditional units of measurement. When Λ is zero, this reduces to the original field equation of general relativity. When T is zero, the field equation describes empty space (the vacuum).

The cosmological constant has the same effect as an intrinsic energy density of the vacuum, ρ_{vac} (and an associated pressure). In this context it is commonly moved onto the right-hand side of the equation, and defined with a proportionality factor of 8π : $\Lambda = 8\pi\rho_{vac}$, where unit conventions of general relativity are used (otherwise factors of G and c would also appear). It is common to quote values of energy density directly, though still using the name "cosmological constant".

A positive vacuum energy density resulting from a cosmological constant implies a negative pressure, and vice versa. If the energy density is positive, the associated negative pressure will drive an accelerated expansion of the universe, as observed. (See dark energy and cosmic inflation for details.)

Explanatory models

Models attempting to explain accelerating expansion include some form of dark energy, dark fluid or phantom energy. The most important property of dark energy is that it has negative pressure which is distributed relatively homogeneously in space. The simplest explanation for dark energy is that it is a cosmological constant or vacuum energy; this leads to the Lambda-CDM model, which is generally known as the Standard Model of Cosmology as of 2003-2013, since it is the simplest model in good agreement with a variety of recent observations.

Dark Matter and Energy

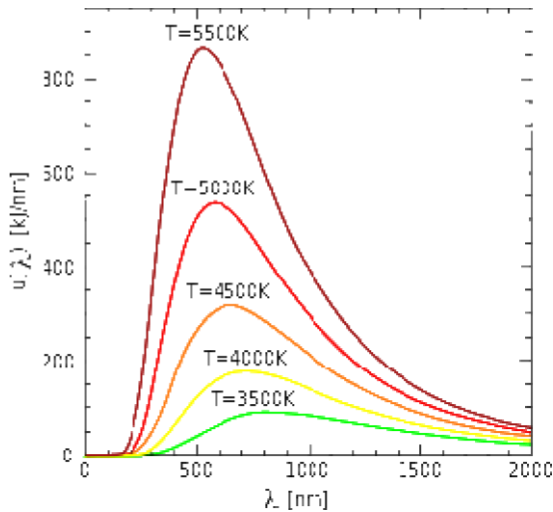
Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large part of the mass that appears to be missing from the universe. Dark matter cannot be seen directly with telescopes; evidently it neither emits nor absorbs light or other electromagnetic radiation at any significant level. It is otherwise hypothesized to simply be matter that is not reactant to light. Instead, the existence and properties of dark matter are inferred from its gravitational effects on visible matter, radiation, and the large-scale structure of the universe. According to the Planck mission team, and based on the standard model of cosmology, the total mass-energy of the known universe contains 4.9% ordinary matter, 26.8% dark matter and 68.3% dark energy. Thus, dark matter is estimated to constitute 84.5% of the total matter in the universe, while dark energy plus dark matter constitute 95.1% of the total content of the universe. [6]

Cosmic microwave background

The cosmic microwave background (CMB) is the thermal radiation assumed to be left over from the "Big Bang" of cosmology. When the universe cooled enough, protons and electrons combined to form neutral atoms. These atoms could no longer absorb the thermal radiation, and so the universe became transparent instead of being an opaque fog. [7]

Thermal radiation

Thermal radiation is electromagnetic radiation generated by the thermal motion of charged particles in matter. All matter with a temperature greater than absolute zero emits thermal radiation. When the temperature of the body is greater than absolute zero, interatomic collisions cause the kinetic energy of the atoms or molecules to change. This results in charge-acceleration and/or dipole oscillation which produces electromagnetic radiation, and the wide spectrum of radiation reflects the wide spectrum of energies and accelerations that occur even at a single temperature. [8]



Electromagnetic Field and Quantum Theory

Needless to say that the accelerating electrons of the steady stationary current are a simple demystification of the magnetic field, by creating a decreasing charge distribution along the wire, maintaining the decreasing U potential and creating the \underline{A} vector potential experienced by the electrons moving by \underline{v} velocity relative to the wire. This way it is easier to understand also the time dependent changes of the electric current and the electromagnetic waves as the resulting fields moving by c velocity.

It could be possible something very important law of the nature behind the self maintaining \underline{E} accelerating force by the accelerated electrons. The accelerated electrons created electromagnetic fields are so natural that they occur as electromagnetic waves traveling with velocity c. It shows that the electric charges are the result of the electromagnetic waves diffraction.

One of the most important conclusions is that the electric charges are moving in an accelerated way and even if their velocity is constant, they have an intrinsic acceleration anyway, the so called spin, since they need at least an intrinsic acceleration to make possible they movement .

The bridge between the classical and quantum theory is based on this intrinsic acceleration of the spin, explaining also the Heisenberg Uncertainty Principle. The particle – wave duality of the electric charges and the photon makes certain that they are both sides of the same thing. Basing the

gravitational force on the accelerating Universe caused magnetic force and the Planck Distribution Law of the electromagnetic waves caused diffraction gives us the basis to build a Unified Theory of the physical interactions. [4]

Lorentz transformation of the Special Relativity

In the referential frame of the accelerating electrons the charge density lowering linearly because of the linearly growing way they takes every next time period. From the referential frame of the wire there is a parabolic charge density lowering.

The difference between these two referential frames, namely the referential frame of the wire and the referential frame of the moving electrons gives the relativistic effect. Important to say that the moving electrons presenting the time coordinate, since the electrons are taking linearly increasing way every next time period, and the wire presenting the geometric coordinate. The Lorentz transformations are based on moving light sources of the Michelson - Morley experiment giving a practical method to transform time and geometric coordinates without explaining the source of this mystery.

The real mystery is that the accelerating charges are maintaining the accelerating force with their charge distribution locally. The resolution of this mystery that the charges are simply the results of the diffraction patterns, that is the charges and the electric field are two sides of the same thing. Otherwise the charges could exceed the velocity of the electromagnetic field.

The increasing mass of the electric charges the result of the increasing inductive electric force acting against the accelerating force. The decreasing mass of the decreasing acceleration is the result of the inductive electric force acting against the decreasing force. This is the relativistic mass change explanation, especially importantly explaining the mass reduction in case of velocity decrease.

The Classical Relativistic effect

The moving charges are self maintain the electromagnetic field locally, causing their movement and this is the result of their acceleration under the force of this field.

In the classical physics the charges will distributed along the electric current so that the electric potential lowering along the current, by linearly increasing the way they take every next time period because this accelerated motion.

Electromagnetic inertia and Gravitational attraction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass.

It looks clear that the growing acceleration results the relativistic growing mass - limited also with the velocity of the electromagnetic wave.

Since $E = h\nu$ and $E = mc^2$, $m = h\nu/c^2$ that is the m depends only on the ν frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_0 inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

If the mass is electromagnetic, then the gravitation is also electromagnetic effect caused by the accelerating Universe! The same charges would attract each other if they are moving parallel by the magnetic effect.

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force.

Electromagnetic inertia and mass

Electromagnetic Induction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass. [1]

Relativistic change of mass

The increasing mass of the electric charges the result of the increasing inductive electric force acting against the accelerating force. The decreasing mass of the decreasing acceleration is the result of the inductive electric force acting against the decreasing force. This is the relativistic mass change explanation, especially importantly explaining the mass reduction in case of velocity decrease.

The frequency dependence of mass

Since $E = h\nu$ and $E = mc^2$, $m = h\nu/c^2$ that is the m depends only on the ν frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_0 inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

Electron – Proton mass rate

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force. [1]

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

Gravity from the point of view of quantum physics

The Gravitational force

The gravitational attractive force is basically a magnetic force.

The same electric charges can attract one another by the magnetic force if they are moving parallel in the same direction. Since the electrically neutral matter is composed of negative and positive charges they need 2 photons to mediate this attractive force, one per charges. The Big Bang caused parallel moving of the matter gives this magnetic force, experienced as gravitational force.

Since graviton is a tensor field, it has spin = 2, could be 2 photons with spin = 1 together.

You can think about photons as virtual electron – positron pairs, obtaining the necessary virtual mass for gravity.

The mass as seen before a result of the diffraction, for example the proton – electron mass ratio $m_p = 1840 m_e$. In order to move one of these diffraction maximum (electron or proton) we need to intervene into the diffraction pattern with a force appropriate to the intensity of this diffraction maximum, means its intensity or mass.

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

The Graviton

In physics, the graviton is a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. If it exists, the graviton is expected to be massless (because the gravitational force appears to have unlimited range) and must be a spin-2 boson. The spin follows from the fact that the source of gravitation is the stress-energy tensor, a second-rank tensor (compared to electromagnetism's spin-1 photon, the source of which is the four-current, a first-rank tensor). Additionally, it can be shown that any massless spin-2 field would give rise to a force indistinguishable from gravitation, because a massless spin-2 field must couple to (interact with) the stress-energy tensor in the same way that the gravitational field does. This result suggests that, if a massless spin-2 particle is discovered, it must be the graviton, so that the only experimental verification needed for the graviton may simply be the discovery of a massless spin-2 particle. [2]

Conclusions

SIMPs would resolve certain discrepancies between simulations of the distribution of dark matter, like this one, and the observed properties of the galaxies.

In particle physics and astrophysics, weakly interacting massive particles, or WIMPs, are among the leading hypothetical particle physics candidates for dark matter.

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy. There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter. The electric currents causing self maintaining electric potential is the source of the special and general relativistic effects. The Higgs Field is the result of the electromagnetic induction. The Graviton is two photons together. [3]

References

- [1] 3 Dimensional String Theory
Author: George Rajna
Publisher: Academia.edu
http://www.academia.edu/3834454/3_Dimensional_String_Theory
- [2] Graviton Production By Two Photon and Electron-Photon Processes In Kaluza-Klein Theories With Large Extra Dimensions <http://arxiv.org/abs/hep-ph/9909392>
- [3] Higgs Field and Quantum Gravity
Author: George Rajna
Publisher: Academia.edu
http://www.academia.edu/4158863/Higgs_Field_and_Quantum_Gravity
- [4] The Magnetic field of the Electric current
Author: George Rajna
Publisher: Academia.edu
https://www.academia.edu/3833335/The_Magnetic_field_of_the_Electric_current
- [5] http://en.wikipedia.org/wiki/Einstein_field_equations
- [6] http://en.wikipedia.org/wiki/Dark_matter
- [7] http://en.wikipedia.org/wiki/Cosmic_microwave_background
- [8] http://en.wikipedia.org/wiki/Thermal_radiation

- [9] <http://hyperphysics.phy-astr.gsu.edu/hbase/astro/univacc.html>
- [10] http://en.wikipedia.org/wiki/Weakly_interacting_massive_particles
- [11] <http://www.darkmatterphysics.com/WIMP.htm>
- [12] <http://news.sciencemag.org/physics/2014/10/dark-matter-out-wimps-simps>
- [13] XENON1T, the most sensitive detector on Earth searching for WIMP dark matter, releases its first result
<https://phys.org/news/2017-05-xenon1t-sensitive-detector-earth-wimp.html>
- [14] Dark Matter Recipe Calls for One Part Superfluid
<https://www.quantamagazine.org/dark-matter-recipe-calls-for-one-part-superfluid-20170613/>
- [15] This New Explanation For Dark Matter Could Be The Best One Yet
<http://www.sciencealert.com/this-new-explanation-for-dark-matter-could-be-the-best-one-yet>
- [16] Dark matter is likely 'cold,' not 'fuzzy,' scientists report after new simulations
<https://phys.org/news/2017-07-dark-cold-fuzzy-scientists-simulations.html>
- [17] Mapping dark matter
https://phys.org/news/2017-07-dark_1.html
- [18] A speed trap for dark matter, revisited <http://www.symmetrismagazine.org/article/a-speed-trap-for-dark-matter-revisited>
- [19] Chasing dark matter with the oldest stars in the Milky Way
<https://phys.org/news/2018-01-dark-oldest-stars-milky.html>
- [20] Synopsis: A Way to Cool Dark Matter
<https://physics.aps.org/synopsis-for/10.1103/PhysRevLett.120.051102>
- [21] New theory of dark matter based on the detection of unusual X-ray radiation from galaxies
<https://phys.org/news/2018-02-theory-dark-based-unusual-x-ray.html>
- [22] Do massive dark matter "nuggets" lurk in our galaxy?
<https://cosmosmagazine.com/space/could-dark-matter-condense-into-solids-100-million-times-bigger-than-the-sun>
- [23] Solving the dark energy mystery: A new assignment for a 45-year-old telescope
<https://phys.org/news/2018-02-dark-energy-mystery-assignment-year-old.html>

