I am Dan McKinsey, and I am a dark matter hunter from Lawrence Berkeley National Laboratory, AMA!

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Abstract

That's a wrap! Thanks for all the great questions today. Don't forget to check out #DarkMatterDay tomorrow via http://www.darkmatterday.com. I'm Dan McKinsey and am here to answer your questions about dark matter, the mysterious stuff that makes up an estimated 85 percent of all matter in the universe, and about how we search for it. My research, before with LUX and now with LUX-ZEPLIN, the next generation of dark matter particle detectors that is under construction at an underground research facility in South Dakota, centers on non-accelerator particle physics, particle astrophysics, and low-temperature physics. In particular, I work on the development, construction, and operation of new detectors using liquid forms of noble gases like xeon, which are useful in looking for physics beyond the Standard Model. Applications for this research include the search for dark matter interactions with ordinary matter, searches for a process known as neutrinoless double beta decay that can help us understand the matter-antimatter imbalance in the universe, and the measurement of the low-energy solar neutrino flux. This talk is one of dozens of events that are related to Dark Matter Day, an international celebration of the search for the unseen on October 31st. Dan McKinsey's Bio http://physics.berkeley.edu/people/faculty/Daniel-McKinsey Dark Matter Day - http://www.darkmatterday.com Ask Symmetry - How is the Force like dark matter? https://www.youtube.com/watch?v=foTNIwSidjc Next-Gen Dark Matter Detector in a Race to Finish Line http://newscenter.lbl.gov/2017/02/13/next-gen-dark-matter-detector-race-finish-line/ Dark Matter day is Approaching... but Don't Be Afraid of the Dark http://bit.ly/lbnl-dmd-reddit Berkeley Lab - http://bit.ly/lbnl-reddit

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DAN-MCKINSEY R/SCIENCE

THAT'S A WRAP! THANKS FOR ALL THE GREAT QUESTIONS TODAY. DON'T FORGET TO CHECK OUT #DARKMATTERDAY TOMORROW VIA HTTP://WWW.DARKMATTERDAY.COM.

I'm Dan McKinsey and am here to answer your questions about dark matter, the mysterious stuff that makes up an estimated 85 percent of all matter in the universe, and about how we search for it.
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Dan McKinsey's Bio http://physics.berkeley.edu/people/faculty/Daniel-McKinsey
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Next-Gen Dark Matter Detector in a Race to Finish Line http://newscenter.lbl.gov/2017/02/13/next-gen-dark-matter-detector-race-finish-line/
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Hello, thanks for answering our questions.

How do you feel about Mordehai Milgrom MOND theory ; do you think Dark Matter actually exist ?

SmellinBenj

MOND can be used to explain the rotation curves of galaxies, and if the rotation curves of galaxies were the only phenomenon we observe that could be due to dark matter, then I would personally hold MOND and dark matter on an equal footing. But there is much, much more evidence for dark matter from the cosmic microwave background, from the lensing of light around galaxy clusters, and from Big Bang nucleosynthesis.

Another difficulty for MOND is the different spatial distribution of ordinary matter and dark matter, as seen in galaxy-cluster collisions such as the Bullet Cluster.

A theory that explains these observations only by changing the laws of gravity has to explain these different phenomena on very different time and length scales in the universe. It is very difficult to

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explain that data in this way. It would have to be an extremely complicated theory that makes predictions that are essentially the same as those predicted by the existence of dark matter.

Hello and thanks for the AMA.

More of a theoretical question but if you could pick a single yes/no question related to your field and have it answered right now, what would it be and how would the answer change our future either way?

Allian42

Is the dark matter a boson or a fermion? All particles in nature are one of those two types, and the way they could interact with ordinary matter depends on whether dark matter is a boson or a fermion.

For example, particles of light (photons) are bosons, and bosonic particles like to clump together in the same state, like in a laser. But fermions, like electrons, are not allowed to be in the same state.

If the dark matter is a fermion, it can't be lighter than 10 electron volts because it will have to spread out into too large of a volume to be consistent with observations.

A dark matter boson could be much lighter. Its wavelength, which is inversely proportional to its mass, could be as large as the galaxy.

What are the best alternative hypothesises to dark matter not existing?

the-player-of-games

Currently, there are no alternate hypotheses that explain all of the phenomena that can be explained by dark matter.

Thanks for doing the ama!

Could dark matter exist on Earth?

Hieveryoneimnew

Yes, dark matter does exist on Earth, and everywhere else.

Hi Dan. Do you think Dark matter could be explained by the presence of molecular hydrogen in space?

zejokeer

Hi zejokeer - No. Ordinary matter, like molecular hydrogen, would contribute to light-element production in the early universe, and there are strict limits on the amount of ordinary matter. It would also create a different cosmic microwave background spectrum than what is observed.

Hi Dan, Thanks for doing this,

What were some of the challenges that were faced while developing the sensors and tech that you will be using in your new facility?

Did anything unexpected come out of that process?

edit: clarity, format

Th_Hamster

Hi Th_Hamster,

One of the surprises is that partway through the LUX experiment, we discovered that charge was building up in the walls of our detector. To remove the charge, we would've had to warm up the experiment (remove the xenon) and start over. We could see the charge based on the observed distribution of event positions in the liquid xenon. The electric-field distortion due to the charge made the analysis more complicated.

Fortunately, we had planned ahead with multiple ways to calibrate the experiment, including using teensy amounts of radioactive krypton that we could inject into the liquid xenon.

The krypton distributed itself uniformly in the liquid xenon, and then by observing the krypton events we could correct for the field non-uniformities.

Hi, Are you optimistic about the chances of detecting dark matter in the near future? Do you believe conclusive evidence will first be discovered via experiments in particle physics, or through astrophysical means (if ever)? Also, what are the principal tools for a dark matter hunter?

Buttstone

The effects of dark matter are so widespread that astrophysicists detect it all the time when they look at galaxy clusters or when they look at the cosmic microwave background, and when they look at light bending around galaxies and galaxy clusters (gravitational lensing).

So dark matter has been detected already in astrophysical ways:

- By its speckle pattern in the cosmic microwave background. That speckle pattern tells us the amount of ordinary matter and the amount of dark matter.
- We know the total amount of matter (ordinary and dark matter) by the amount of galaxy formation, but the amount of ordinary matter can be measured by the production of hydrogen, helium and lithium in the early universe, and this points to only a small amount of matter in the universe being ordinary matter - the rest has to be dark, not participating in light-element production in the early universe.
- We can image dark matter through lensing of light around galaxy clusters. This tells us the distribution of matter in the galaxy cluster. Amazingly, there are examples where the ordinary matter and most of the gravitationally interacting matter are spatially separated. We can image the ordinary matter with X-rays or visible light. This shows up, in some cases, in a different place from the matter that's causing gravitational lensing.

Can you share if you will be looking to prove or disprove the theory of weakly interacting massive particles? How will you do that?

AA_2011

Yes. The LUX-ZEPLIN (LZ) experiment, which is under construction in South Dakota, is designed to test the WIMP hypothesis. The experiment is a tank of 10 tons of liquid xenon, about a mile underground in a former gold mine. The experiment is built of ultra clean materials like purified titanium and teflon and uses very sensitive light detectors to look for flashes created by WIMPs scattering with xenon nuclei.

What are some of the more unusual yet plausible theories about dark matter that you've heard about?

Xenoprimatology

Hi Xenoprimatology,

Some new ideas imply that the dark matter could be extremely low in mass, like 10 to the minus 22 in electronvolts. If the dark matter is extremely light, and interact with ordinary matter more like a wave than as individual particles, this ultralight particle could be something called a dark photon or an ultralight axion. There are other new experiments that are being built or are proposed to test these hypotheses.

I've heard widely different numbers about how much of the mass of the universe is this so called dark matter - from 50% to 85%.

What are the best, most widely accepted, estimates?

If the estimates vary by so much, how likely is it that dark matter is simply regular matter hidden in the error bars?

The dark matter question reminds me of the ether people we're trying but failing to detect before Einstein. If you fail to conclusively detect dark matter, at what point does that become indicative that it simply does not exist? How do you tell you are not detecting it because it does not exist vs it simply being hard to detect / undetectable? Maybe it's just entanglement, dark matter is there but trying to decide it makes it undetectable??

ventsyv

There are different ways to state the amount of dark matter in the universe. You can talk about the fraction of matter that is dark matter and you can talk about the fraction of the mass (or energy) that is dark matter.

Dark matter is 85 percent of the matter in the universe, and about 27 percent of the mass-energy density of the universe. These numbers are actually both quite precise.

They are both precisely determined from the combinations of astrophysical measurements, and especially the amazing data from the cosmic microwave background.

Whats your opinion on candy corn?

InspiredGeophysicist

Candy corn is NOT dark matter.

Hi, Dan and thank you for the AMA! If we could somehow isolate dark matter, are there any possible applications we could use it for?

paddjo95

Hello paddjo95,

I don't think we can ever isolate dark matter, because no bottle can hold it. We already know that dark matter, like neutrinos, interacts too weakly for it to be contained. There was an idea to use one

theorized form of dark matter, called axions, for communications, instead of light, but this is kind of far-fetched. Light has to go around Earth's circumference to get from one place for another, but axions can go right through the Earth!

Physicists giving presentations to lay audiences often say, "There are 10^{x} particles of DM passing through your hand every second!", but then others say, just as readily, "We don't know what DM is, we don't even know if it's made of particles yet!"

Well, is it made of particles? And if so, do we know the mass of these particles?

AFAIK (As Far As I Know) electrons are considered by Standard Model physicists to have no size; to be point masses. Can you say anything about the size of DM particles, eg. upper and lower limits, or other restrictions on the range of possible sizes?

Do Standard Model physicists, i.e. those at CERN etc., concern themselves with DM? Are theoreticians trying to fit it in to the SM? How about string theorists?

Thank you very much. Personally I find DM to be more intriguing than Dark Energy.

iHaveAgency

Dark matter IS made of particles. In our framework for understanding the universe, everything is made of particles. There are very few limits on the size of dark matter particles. They may be pointlike like electrons, or they may have some structure. They can't be so large that they cause microlensing - brief enhancements in the light from stars or galaxies from gravitational lensing.

CERN is primarily looking for physics beyond the Standard Model, and one of the most important goals of the Large Hadron Collider (LHC) is to produce dark matter particles and see evidence for this production through momentum and energy imbalances in the Standard Model particles that they can detect directly. All particle physicists are looking for physics beyond the Standard Model, so there are no Standard Model particle physicists! The goal is to discover something new.

Many theoreticians think about dark matter and how to detect it, and what it's properties might be, but no matter what it is - it's not part of the Standard Model. It's "new physics."

Hi Dan! I've always had a strong interest in theoretical astrophysics, and dark matter intrigues me, but I don't really understand it well, and can't find any good summaries. Can you give a brief explanation of what it is and the implications of its existence?

Astrobomb

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Hey, thanks for doing the AMA !

- Could you walk us through the process used to discover dark matter ?
- Is there any way to interact with, manipulate it in a form or another ?
- What would you say is the most difficult part of the data to obtain, how do you tackle it?
- Have you ever had a "genius" moment that caused a leap in your work? If yes, what was it?
- How do you explain what you do to someone who has no background in physics and how do you explain it to someone who does?

Thanks

DiogenicOrder

Hi DiogenicOrder - 1. The experiment is built of ultra clean materials like purified titanium and teflon and uses very sensitive light detectors to look for flashes created by WIMPs scattering with xenon nuclei. 2. Our goal is to discover how dark matter interacts with normal matter. Once we discover this, we may find a way to manipulate it, but it will likely be very hard to manipulate because it interacts so weakly. 3. Radioactivity is all around us, always, from naturally occurring isotopes that are typically trace impurities in every material. Even you and I are radioactive because of potassium in our bones. Other radioactive isotopes include thorium and uranium, and these make gamma rays and neutrons that can scatter in the liquid xenon and create background that can hide the WIMP or other dark matter scatters. So we have to go to great lengths to use materials that are extremely clean, and we have to shield our experiment in a tank of ultra pure water, because the tank around the experiment is radioactive, too. 4. As for the "genius" moment, most of my favorite ideas have happened when I am in the shower in the morning. Most of the best ideas happen by taking two or three ideas or more and connecting them in a synergistic way. I'm an experimentalist and I mostly think about new detector technologies. One of my favorite new ideas is to use superfluid helium to detect dark matter that's lighter than WIMPs.

1. Each of our experiments is a complicated project, with many people who contribute different skills. It's a team effort. We're bringing together all the parts that are needed to develop and implement a new technology. Like inventing a new type of car or smartphone. Our immediate goal is not to develop commercial products, but to create a new technology that can discover the nature of dark matter.

Explain to me like I'm 5 years old: What is dark matter?

RLangdon9

For all I know you are 5 years old! Dark matter is an invisible substance that causes galaxies to form and large-scale structures - the clumpiness of galaxies and clusters of galaxies - in the universe to be created. It interacts gravitationally and there's evidence for that at many different time and length scales in the universe. But we don't know exactly how dark matter was created and how it interacts with ordinary matter.

Without dark matter, many galaxies would not have formed, and maybe even our own Milky Way galaxy would not exist.

Thanks for your time. Does it seem more likely that dark matter is concentrated nearby normal matter, or that it tends to be in empty space where there is no matter? Why?

h8speech

In most cases, dark matter is concentrated near normal matter. That is not a coincidence, because dark matter forms the gravitational potential into which ordinary matter falls to form galaxies. Because when dark matter clumps together, it pulls ordinary matter toward it. Then, the ordinary matter like hydrogen and helium, etc., can start to interact and make stars and galaxies.

How far is the nearest dark matter? Would we able to get some?

xipha

Xipha,

Dark matter is everywhere. It's whizzing through you every second of your life. You can't bottle it because it won't stay in the bottle, and you can't buy it in a store or from physicists.

Why does magnetism alone do an insufficient job of explaining what we observe as Dark Matter?

JustTray

Magnetism would not cause light to bend around galaxies and galaxy clusters in the way that we observe. It would not explain the ratio of matter to dark matter observed in the cosmic microwave background.

Why does dark matter have to be this special and different thing. Can't it just be normal matter that's just not illuminated by any energy source and therefore not detectable?

g3rain1

Clouds of dust and gas have light going through them, such as the light, radio waves and microwaves produced by hydrogen that are ubiquitous in the universe. These allow us to image the clouds of dust and gas and put limits on how much of this there is in the universe.

Also, the speckles of light from the cosmic microwave background a particular ratio of ordinary matter to dark matter, and demonstrate that there's much more dark matter than ordinary matter.

In the Big Bang, elements like hydrogen, helium, and lithium are produced, and from the observed ratios of these elements we can calculate the amount of ordinary matter. This amount of matter is not enough to explain the observed amounts of clustering of matter in the universe.

What actually is dark matter? Is it made of atoms, is it a chemical compound, what state does is exist as...?

lottie_adams_

We don't yet know what dark matter is, we only know that it interacts gravitationally. Simple models of dark matter predict that it's just point like particles like electrons and quarks. But just like quarks cluster to make neutrons and protons, it's possible that dark matter clusters as well to make dark matter nuclei or even dark matter atoms.

[deleted]

[deleted]

The slight imbalance between matter and antimatter is so far unexplained and also a crucial question in physics. As far as we know, dark matter doesn't directly explain this, but it could be that if we detect dark matter it will give us clues to physics beyond the Standard Model and help us to understand the matter-antimatter asymmetry of the universe.

if we have a multiverse, what is outside the edge of our universe? candy corn?

InspiredGeophysicist

It might be candy corn, for all I know! I don't think we'll ever find out what's outside our universe, by definition, because the universe is everything we can see.

Hi Dan,

Why do you think the physics community ignores Occam's Razor when it comes to gravity? We know Newtonian mechanics are extremely accurate at solar system scales, no DM/DE required, yet when we move to galactic scales it no longer suffices. Isn't the simplest answer we just don't understand the underlying mechanics of gravity?

Scroofinator

Occam's Razor is the principle of parsimony that nature will choose the simplest solution among a range of options.

Dark matter is the simplest solution to explain all of these observations at once. These include the cosmic microwave background, power spectrum, the lensing of light around galaxy clusters, the amount of structure formation we see in the universe, the velocities of galaxies and galaxy clusters, and the rotation curves of galaxies - all at once, with one simple explanation.

All other explanations are more complicated.

So the dark matter explanation is indeed favored by Occam's Razor.

Hi and thanks for doing this AMA!

How do the experiences you work on propose to help us find dark matter?

What time do you expect to wait before you have significant data?

Hafornin

The LUX-ZEPLIN (LZ) experiment, which is under construction in South Dakota, (like the LUX experiment before it) is designed to test the WIMP hypothesis. The experiment is a tank of 10 tons of

liquid xenon, about a mile underground in a former gold mine. The experiment is built of ultra clean materials like purified titanium and teflon and uses very sensitive light detectors to look for flashes created by WIMPs scattering with xenon nuclei. We already have significant data from the LUX experiment, which was used to rule out several particular WIMP models, like the so-called well-tempered neutralino. LZ, our new experiment, will be 50 times more sensitive than LUX, and it will start taking data in 2020.

Hi! My first question that comes to mind is what are the implications of discovering dark matter? What does it mean for the scientific community and the world beyond?

jt4797

The existence of dark matter is one of our most significant clues to discovering new laws of physics. Once we discover dark matter we can learn how it interacts with different kinds of nuclei and other particles, and uncover the rules by which it behaves.

Those rules could point to new phenomena that we could look for, and other new particles that we could try to produce in accelerators.

Discovering the nature of dark matter may also provide us new astrophysical phenomena to search for, and help us understand the evolution of the universe in more detail.