Hi! We are scientists with the ADMX collaboration, and our experiment is the best chance of discovering a type of dark matter called the axion. Ask us anything!

ADMX$_{C}ollaboration^{1}andr/ScienceAMAs^{1}$

[1]Affiliation not available

April 17, 2023

Abstract

What we do: Dark matter is a mysterious form of matter that makes up 80% of the matter in the universe. We call it dark matter because it doesn't emit or reflect any light or radiation, so it's basically invisible. The ADMX experiment looks for a theoretical type of dark matter known as the axion. These hypothetical particles were developed to solve problems in nuclear physics, but its properties also make it a very promising dark matter candidate. The detection of axion dark matter would solve two of the biggest mysteries in physics. ADMX is an incredibly sensitive detector that functions a lot like an AM radio and tries to "hear" a particular signal from axions. We just published results from our most recent science run, where we achieved an unprecedented sensitivity to axion dark matter that makes us the first experiment to probe the most likely areas for axions. Ask us all your axion, dark matter, and science questions! The ADMX Answering Board: University of Washington (UW) Gray Rybka: Gray is a professor at the University of Washington and a spokesperson of the ADMX experiment. He works on data taking and development of the analysis package for the main experiment housed at UW. Rakshya Khatiwada: Rakshya is a postdoc at the University of Washington. She works on the development and implementation of the current and future ADMX detectors containing cryogenic electronics package along with the system noise temperature characterization. This package houses a number of radio frequency electronics components, including quantum-noise-limited amplifiers, which allow ADMX to reach its high sensitivity. Chelsea Bartram: Chelsea is an incoming postdoc to the University of Washington. She is currently finishing her PhD at the University of North Carolina, Chapel Hill, working on searching for CP violation in lepton number with the CALIOPE experiment. Nick Du: Nick is a graduate student at the University of Washington. He works on the main ADMX experiment developing the sensors package for the experiment and implementing a blind axion injection scheme for the experiment. Lawrence Livermore National Laboratory (LLNL) Gianpaolo Carosi: Gianpaolo is a staff scientist at Lawrence Livermore National Laboratory and a spokesperson of the ADMX experiment. His group works on designing and implementing the motion control systems for the cavity and coming up with future designs for higher mass axion experiments. Nathan Woollett: Nathan is a postdoc at Lawrence Livermore National Laboratory. His group works on testing components of the ADMX cold electronics package before it gets added to the main experiment. He is also working on different detector designs for higher mass axion searches. Fermilab National Accelerator Laboratory (FNAL) Daniel Bowring: Daniel (@doctorbowring) is a physicist at Fermilab, working to design, build, and control new types of particle accelerator. His work for ADMX focuses on detector design, and specifically on cooking up new ways to improve our signal-to-noise ratio. Akash Dixit: Akash is a graduate student at the University of Chicago. He is working on developing photon amplifier and detector technology for use in axion searches at higher masses. Pacific Northwest National Laboratory (PNNL) Christian Boutan: Christian is a postdoc at Pacific Northwest National Laboratory. He started out as a graduate student at the University of Washington where he created an experiment looking for higher mass axions known as Sidecar. He now works at PNNL on designs for the next run of ADMX which will feature an array of 4 cavities tuned to the same frequency. University of California Berkeley (UCB) Sean O'Kelley: Sean O'Kelley is a graduate student at the University of California Berkeley. His lab works on developing extremely low noise amplifiers, known as Superconducting QUantum Interference Device (SQUID) amplifiers. The ultra-low noise of these amplifiers is part of what allows the experiment to reach its high sensitivity. Publication: Search for Invisible Axion Dark Matter with the

Axion Dark Matter Experiment Press Releases: University of Washington Lawrence Livermore National Laboratory Fermilab University of California, Berkeley Social Media: Web Page Twitter Edit: Hi all! Thanks for all of your great questions. We had a lot of fun answering all of your questions! Until next time!

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ADMX_COLLABORATION R/SCIENCE

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Publication: Search for Invisible Axion Dark Matter with the Axion Dark Matter Experiment

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Edit: Hi all! Thanks for all of your great questions. We had a lot of fun answering all of your questions! Until next time!

CORRESPONDENCE:

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What is the structure of dark matter bodies in our universe? Is it found in clumps, spheres, rings etc. , or universally spread out.

The_impericalist

Great question! Dark matter clumps together because it's gravitationally attracted to itself. Imagine a large, weakly interacting cloud that extends past the visible edge of our galaxy. However, the distribution of dark matter within galaxies may actually turn out to have a lot of detail. For example, if dark matter is made of axions, they may form a Bose–Einstein condensate, creating a series of high density dark matter rings within our galaxy that would have a low velocity dispersion and therefore a very narrow signal bandwidth from the perspective of our experiment, ADMX. This is not widely accepted in the community but it is a possibility. When you get to larger scales, like 10-100 megaparsecs, the distribution of dark matter looks more like a giant spider web. Check out these simulations, in which one pixel = one galaxy cluster! Edited for clarity: If we find the axion, other experiments could quickly be set up all around the world to confirm the finding and put new constraints on galactic evolution. (C. Boutan)

Hello, nice to talk to you. I am very much a lay man when it comes to all forms of dark matter so I'm gonna ask very layman questions.

What are the practical benefits of this?

Does dark matter have any other known interesting properties?

Since it's so invisible, could it be used for cloaking technology?

"solve two of the biggest mysteries in physics." But what are those mysteries?

Mike_Handers

These are all great questions! We'll try to answer them one at a time. First, we don't know enough about dark matter to understand what the practical benefits might be. Is it a light particle, a heavy particle, a quirk of gravity/relativity? Hard to build technology based on that level of uncertainty. However, practical benefits often follow fundamental discoveries. For example, people got interested in semiconductors because of their unique physical properties. Ultimately, that interest gave rise to solid-state transistors, the modern semiconductor industry, and devices like your computer or mobile phone.

This is why fundamental research is so important -- apart from discovery being a beautiful and vital part of the human experience, we can't build technology based on phenomena we don't understand. See also: 60-ish years after their first direct detection, people are starting to understand neutrinos well enough to propose interesting new technology, like radiation monitors. Since axions interact so weakly with regular matter, you might imagine some sort of communication protocol based on the "light shining through walls" phenomenon. (D. Bowring, S. O'Kelly)

Because we don't know what dark matter *is*, it's hard to talk about its properties. Most physicists are confident that axions are stable (i.e. they don't easily decay into other particles), weakly interacting through the fundamental forces, cold (i.e. non-relativistic). (C. Boutan)

"Cloaking" technology has to absorb or redirect light. Dark matter is so weakly interacting with regular matter and light that it wouldn't be much good for this. (D. Bowring)

"Two of the biggest mysteries in physics": (1) What is dark matter, and (2) how do we solve the Strong CP Problem? (C. Boutan)

Is dark matter a "form of matter?" Like gas, liquids, and solids. If it is then would dark matter just simply be matter in a different form, and so we could duplicate dark matter on Earth?

KNEternity

Good question! Solid, liquid, and gas are what we call a state of matter. For example, water can exist as a solid, liquid, or gas. Instead, we're thinking about *types* of matter. On a cosmic scale it's useful to chunk up types of matter into these categories: things made of atoms (i.e. bosonic matter), things made of dark matter, radiation, or dark energy. We don't know the form of dark matter, which is why experiments like our are interesting. Typically, scientists detect new particles by exploring their interaction to the known four fundamental forces -- gravitational, electromagnetic, strong and weak. Dark matter (e.g the axion) does not seem to interact strongly with any of these forces. This means we need clever techniques to detect dark matter compared to ordinary matter. In principal, if we find the axion, we should be able to create them here on Earth. This is similar to creating the Higgs boson in particle accelerators -- it gets easier once we know its mass and other properties. If axions are the form of dark matter there is a type of experiment which can be used to look for them where we create them and detect them in the same experiment, this is called a light shining through wall experiment. Hope this answers your question. (R. Khatiwada, N. Woollett)

Hi! Thank you for taking the time to answer our questions :)

After how much time checking a particular frequency would you expect to record anything if that is the frequency of the axion? What is it about an axion that would make it so "indifferent" to EM radiation? Are axions expected to exist in the standard model or were they postulated to specifically resolve the issue of dark matter? Would you expect to find axions of different generations, or flavours? How long have you been working towards building a detector for axions?

Best of luck for the experiment!

5davide5

Thanks for your questions! We love challenging questions like this! We'll be answering your questions one by one. **After how much time checking a particular frequency would you expect to record anything if that is the frequency of the axion?:**

The time it takes to detect an axion depends on a number of experimental parameters: magnetic field strength, cavity volume, cavity temperature, etc. In our case, we expect to start to see something anywhere between 1-20 minutes. There is some uncertainty because the amount of power the axion will deposit in our experiment depends on the model for the axion. Getting the time down this low was no easy task either, it took 30 years of blood, sweat, and tears from a bunch of scientists to get us to a point where we can detect axions so quickly.

What is it about an axion that would make it so "indifferent" to EM radiation?

Sorry, I’m not quite sure what you mean by this question, but I’m gonna try my best to answer it. The axion has no electric charge, so to a first approximation, it doesn’t interact with EM radiation. Quantum mechanics lets weird things happen, like an axion turning into some quarks, and those quarks turning into some photons. If this sounds improbable, it is, but it’s NOT impossible, and it is exactly this interaction that we hope to use to detect axions. The strong magnetic field and resonator in ADMX help to boost the rate of this very rare occurrence.

Are axions expected to exist in the standard model or were they postulated to specifically resolve the issue of dark matter?

So axions actually came about as a possible solution to another major problem in physics, called the “Strong CP” problem. The “Strong CP” problem can’t be explained our current standard model, so I see it as the axion filling a gap within the existing model. As it turns out, the properties of the axion also make it a dark matter candidate if it has the right mass, so if our experiment were to find the axion it would solve two of the biggest problems in physics.

Would you expect to find axions of different generations, or flavours?

The simplest model for axions has only a single flavor, however there are theorists out there who have put out theories suggesting the existence of a whole bunch of flavors of axions. Our experiment looks for only a single flavor axion.

How long have you been working towards building a detector for axions? Best of luck for the experiment!

So this experiment began in its original form about 30 years ago. It started out in Lawrence Livermore National Labs, before moving to the University of Washington in 2010 and has undergone several major upgrades. It’s only in the last few months that we’ve achieved the sensitivity theory says we need to detect axions, or definitively say they are not around.

-C. Boutan, S. O'Kelley, N. Du

If the universe is homogeneous, shouldn't we have dark matter close to us and if there was some close to us, would we even be able to detect it?

Also; if dark matter has mass, shouldn't we be able to detect its gravitational pull?

[Nohx]

Yes, kind of, and yes! The homogeneity of the universe is known a the Cosmological Principle, though that Principle only really applies on scales much larger than individual galaxies. We know that dark matter “clumps up” via gravitational attraction, and we think we’re in a sufficiently clumpy region of the universe that we should be able to detect dark matter here on Earth. If axions dominate this dark matter, their local density might be $10^{14/cm^3}$ An analogy with neutrinos is appropriate: dark matter should be all around us, and we just need to build the right experiment in order to see it. Our detector is made to catch an occasional passing axion and turn it into a photon, which we can detect. In principle, one could detect dark matter by its gravitational pull, but that is really technically challenging (because gravity is so weak) so that not how we have designed our experiment. (D. Bowring, C. Boutan, S. O'Kelly)

How many different particles are currently considered good candidates for dark matter along with the Axion? How does the Axion compare/differ from them?

The recent discovery of [hydrogen clouds from the first stars] contained hints of dark matter particles with a mass close to that of a proton. Are the Axion mass estimates within the range that they could have been responsible for the cooler than theory predicted hydrogen clouds in the early universe?

shiningPate

Theorists are creative, so there are lots of candidates. Measurements of the cosmic microwave background (CMB), baryon acoustic oscillation (BAO), and big bang nucleosynthesis tell us that dark matter must be mostly cold and non-baryonic (i.e. not made of atoms). That rules out a lot of candidates. Today, it seems like the particle physics community has picked a couple front-runners. Weakly Interacting Massive Particles (WIMPs) are heavy and, unlike axions, detectable via scattering off of atomic nuclei. WIMPs are still viable but have not been found. Obviously, our group is excited about axions, which are lighter and more easily detectable through wave interactions. If I'm not mistaken, the Nature paper that you're referring to actually suggests that dark matter is a lot lighter than everyone expected. On page two of the Barkana paper (linked to in the article you posted) the claim is that dark matter masses should be less than 4.3 GeV and says “There is no lower limit on the mass except for the extreme limit derived by considering ultra-light (‘fuzzy’) dark matter, namely, m ≈ 10–31 GeV”. To me, that points to axions which are in the uev-meV range. (C. Boutan, N. Woollett, D. Bowring, C. Bartram)

Hi, thanks for this AMA. I'm an undergrad in physics and we've talked a bit about WIMPs and axions in one of my classes recently, so I'm excited to get to talk to one of the experiments directly!

In your title you claim your experiment has the best chance of discovering an axion. What motivates this claim? How does your experiment compare with other experiments looking at different masses?

What's the time scale like for covering the mass range you want to cover?

iSuck7

Hi, glad to hear that you covered WIMPS and Axions in your class! Delighted to talk to you. The main motivation for saying that ADMX has the best chance of discovering axion is that it is the only axion experiment that has reached the sensitivity necessary to detect or exclude axion dark matter. Axion has a wide range of possible mass extending from meV to **μ**eV. ADMX experiment is sensitive to the right range of mass (we call it the “sweet spot”) that could make up just the right amount of dark matter (not too low and not too high) that we predict exists in the universe. There are other experiments which cover this mass range as well but they are not as sensitive as ADMX to detect the axion yet if it exists. Regarding time scale, since we do not know the exact mass of the axion and only know the range of masses but have the sensitivity to detect it, we could detect it anytime -- today, tomorrow or a few years later if its mass falls farther than the current ones we are scanning. Our scan rate is currently tens of kHz per 100 seconds. (R. Khatiwada)

What are axions (theoretically) made of? And what do you anticipate to be the largest challenges of the study?

JoeTheShome

The first question is easy and the second is more involved. An elementary particle is not made up of smaller building blocks, that's what makes it elementary. Other fundamental particles include electrons, quarks, and photons. To your other question: There are two main challenges we anticipate. 1. We have to search over a wide range of potential axion masses. As we sweep across increasing axion mass/photon frequency, the size of our receiver (cavity) will have to shrink. This is the same phenomenon as a fretted (i.e. shorter) guitar string having a higher pitch (frequency). To overcome the decreasing detector volume we are trying to combine the signal from multiple cavities, ganged together. 2. As the frequency of our search increases, the noise in our signal will also increase. To mitigate the effects of this unavoidable added background we need to rethink our strategy for signal analysis. We have some ideas on the drawing board for how to do this too. Edited to add individual attribution for this answer: (A. Dixit and C. Boutan)

Hi, thanks for doing this AMA! Sorry that this is a bit of a fundamental question instead of specifically on ADMX, but would you be able to explain why the majority of physicist favour dark matter over modified gravity? I'm aware that all current MOG hypotheses have observational flaws to varying degrees, but given that dark matter is yet to be observed either, what makes many experts believe that one is more likely than the other?

HawkinsT

Hi HawkinsT, This is a great question! The dark matter hypothesis is a result of many different astrophysical observations from many different experiments. Explaining any one of these observations with modified gravity is (relatively) easy. Explaining all of them with modified gravity yields a very complicated and ad-hoc theory (if it even works at all). Despite the attraction of a modified theory of gravity, a new particle that makes up dark matter is by far a simpler explanation.

So "believe" is maybe not the right way to characterize it "suspect" or "have a hunch" might be more accurate.-- For real, no one knows what dark matter is, and maybe the fairest description of what we mean when we say "dark matter" is "a mismatch between what we think we know and what we actually see". Mismatches like that are a sign that nature is telling us there is something important to learn, and that's the kind of thing that gets scientists excited. It's important to think creatively when faced with such a conundrum, so I'm glad there are several ideas with different people working on them about what dark matter is. Speaking for myself, here's why I like the conventional dark matter picture (of which axions are a particular model): The first hint of dark matter is from rotating galaxies: they seem to be spinning so fast they should fly apart, unless there is some extra invisible gravitational mass holding things together. The second is gravitational lensing: we can tell how much mass is in a galaxy by how much it bends light coming from stuff behind it. The cool thing is that the mass measurements from these two measures of mass match up! The third way to measure dark matter is to look at the large-scale structure of the universe, both from the "shape of things now" and from the lumps in the early universe we can see in the Cosmic Microwave Background (CMB). (more clumpiness means more mass) The amount of mass we infer from these "cosmic clumpiness" measurements *also* matches the amount of matter (dark and normal) we infer from the first two measurements. All in all, when I look at the data we have, it looks most like the conventional dark matter picture, so that's what I work on. All the same, I'm glad other smart people are working on things like MOD, because as a general principle of intellectual humility, it's important to remember everything you know might be wrong. (S. O'Kelly, G. Rybka)

Is there any theory to accomodate a dark matter particle that does not break the existing standard model? If you discover the Axion, is there an existing slot in the model for it to fit? If not, does adding another row or column to the existing matrix of particles necessitate other dark matter particles as well?

shiningPate

We'd say the Standard Model is incomplete, rather than unbroken. It describes nearly every physical phenomenon that's part of our human experience, but there are some big questions left unanswered: What is dark matter? Why is there more matter than antimatter in the universe? etc. A really fascinating aspect of the current physics landscape is that after the discovery of the Higgs boson, we're really in a mode of "unknown unknowns". If we discover the axion, there's plenty of room in the Standard Model to accommodate it. In terms of theory, axions are the solution to the strong CP problem in the current Standard Model. The proposed solution to the strong CP problem requires axions; therefore, it does not break the current standard model but helps explain the current problem in strong sector of Standard Model quite elegantly. Therefore, axion searches are also motivated strongly by this aspect of the theory. If the axion is discovered, it will fit nicely with the current standard model extension -- the solution to the Strong CP problem in the Standard Model. (D. Bowring, R. Khatiwada, N. Woollett)

What is your favorite dinosaur?

What was your favorite track off of DMX's album, it's dark and hell is hot?

bozobozo

"For My Dogs" gets votes from several of us. If we go wide, then of course we should include "What's My Name?" and "X Gon' Give It To Ya". At present we have no rivalry with the IceCube experiment.

The question about dinosaurs is generating a lot of debate. This is a very personal issue, it turns out. *Akash likes Littlefoot from "The Land Before Time" *Chelsea is a fan of the liopleuodon. *Sean likes the peregrine falcon. It's totally a dinosaur. A dinosaur that learned to fly and dive-attack pigeons. Awesome. *Nathan doesn't like to pick favourites, they are all special. He does however like the idea that dark matter dislodged the meteorite that took out the dinosaurs and our experiment is all a quest for vengeance. *Nick agrees with Akash that "Land Before Time" had the best dinosaurs, but insists that Spike is clearly superior to Littlefoot. *Daniel likes the quetzalcoatlus, which is technically a pterosaur but obviously and completely owns. *There's a dark matter experiment called TREX, by the way. (Edited for formatting.)