Science AMA Series: We're Jorge Cham (creator of PhD Comics & PhD in Robotics) & Daniel Whiteson (particle physicist & CERN researcher). We wrote a book called WE HAVE NO IDEA about the biggest unanswered questions in the Universe! Ask us anything!

$\mathrm{WE}_{H}AV\,E_{N}O_{I}DEA^{1}andr/ScienceAMAs^{1}$

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Abstract

Hi, reddit! There are so many things we don't know about the Universe. For example: What is most of the Universe made of? What is dark matter? Where does dark energy come from? Why does the universe have a speed limit? What (or who) is attacking earth with tiny, super-fast particles? And for that matter... what is matter? After generations of human research, brilliant scientific minds, and crazy technological advances we can confidently answer all of these questions the same way: we have no idea. In our new book WE HAVE NO IDEA: A Guide to the Unknown Universe we talk about why a vast portion of our universe (read: most of it) is still a mystery, and what a lot of smart people are doing to understand it. Ask us about physics, the universe – known and unknown, the Large Hadron Collider at CERN (Daniel works with it), illustration (Jorge's the creator of PHD Comics), science in general, our deepest hopes and fears – in other words... ask us anything! We will be back at 4 pm ET (1 pm PT) to answer your questions.

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REDDIT

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WE_HAVE_NO_IDEA R/SCIENCE

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Which of the unanswered questions you wrote about will be answered first? Why would you predict this?

belike1

Wow, this is a great question thanks for asking it. Some of the questions we wrote about are more immediate research questions, like "what is dark matter" compared to bigger broader questions like "what is time?".

So it would be easy to say that the dark matter question would be answered first.

BUT! (You knew there would be a but). But, science doesn't work that way, offering answers to the questions we asked. Very often, asking one specific research question leads to new broad questions rather than specific answers. Remember that the discovery of dark matter (>50 years ago) came out of asking a different, very specific and minor-seeming question: are galaxies rotating at the speed we expect them to? That seemed like a detail, but it cracked open a great cosmic mystery.

So it's really impossible to predict where answers or new questions will come from, and so we would

about the biggest unanswered questions in the Universe! Ask us anything!, *The Winnower* 4:e149458.86246 , 2017 , DOI: 10.15200/winn.149458.86246

be foolish to predict. (But I really want to know what dark matter is, and soon!)

Science is much more fun than Hollywood movies, because you can never predict the ending.

What is your take on the Fermi paradox?

Figge142

Great question, and we have a whole chapter on this in the book! For those who don't know the Fermi paradox: if the Universe is so big and old, why isn't it crawling with life and why haven't we been visited yet?

First, I have to say that I agree with PhelanIainMacPhail that it's impossible to answer the question completely if you think of the broadest definition of life. This is part of the general problem: we have only one example of a planet with life, so we don't know the answer to the basic question: what forms can life take? Even here on Earth biologists are still debating about where to draw the line. Are viruses alive? So if life could be any self-replicating system, then the simplest answer to the Fermi paradox is that it's most likely to be so alien that we just can't even recognize it. It could operate on cosmic timescales, or much shorter timescales, or communicate in ways that are unimaginable to us. We simply don't know how much we don't know.

But, we can slice away most of that (without any justification) and reduce the larger question to a smaller question that is still interesting: Is there intelligent life that is similar to us? In that case we have a clearer definition of what intelligent life is (though the boundary of 'similar to us' is pretty vague).

In that case, there are billions of Earth-like planets in our galaxy. But to take the Fermi paradox seriously you have to argue that the chances of life being created are not small, and the chances of life developing intelligence and technology are not small. The problem is that we don't know that. The chances of life evolving given the right circumstances could be 1/trillion or ½. We don't know because we have only one positive example. The chances of intelligence evolving could be similar.

So: we have no idea!

What are the biggest questions to come from using the LHC? Things we didn't know to ask until we had that resource?

Zizerix

There are a lot of questions that we asked before the LHC turned on: are there new particles? Can we make dark matter? Is there a Higgs boson and how much mass does it have?

Since we turned it on, we found the Higgs boson, answering that one question. So far, we haven't found dark matter or any other new particles.

But there is a new question that comes from the Higgs boson discovery: why does it have the mass that it does? The Higgs has the mass of 125 protons, which is very light. In the current theories, there are two things which control the mass of the Higgs boson, one that makes it heavy and one that makes it light. These two things seem totally unconnected in our theory, and they are both very powerful, at scales of billions of protons. So the weird thing is that they seem to balance almost perfectly, giving the Higgs this fairly small mass. It's like if you chose two random numbers between 1 and 1 trillion, and the numbers came out within 100 of each other. Physicists are wondering if that's a weird coincidence, or if it's a clue that these numbers aren't unrelated, but connected somehow.

Hi Jorge,

What's your favorite reader-inspired comic idea?

PS:

Back in 2009, I drove you to O'Hare airport at 5 a.m. to catch a flight. I started to chat with you right away, and after politely engaging me for a little while, you looked at me and asked if I minded if you slept, like any normal person would do. So I drove for about an hour in silence while you slept in my front seat.

I recently traded the car in. The dealer's daughter is a PhD student and had given her dad a copy of your book, which he had sitting on the table in the waiting area. I noticed it and mentioned to him that "Jorge Cham once slept in the front seat". This helped me get an extra $120 on the trade in.

Thanks, Jorge!

boonamobile

hi! Thanks for the ride and letting me sleep! I think remember that day! Purdue? Sorry I wasn't more conscious to talk, but if it's worth $120, I should sleep in people's cars more often!

One of my favorite reader-suggested comics is the one that compares Kindergarten to grad school.

Which theoretical discovery will change the world most if it is proven true?

CowZix

I looove this question, because it recognizes that these science questions have important personal and philosophical implications. That's why we wrote this book, because these questions impact everyone, and unlike some philosophy questions, they actually have hard answers that we can learn!

I think that learning about how the Universe began would really affect how people think about the human situation. If we learn that our Universe is one of an infinite number of Universes, then it's another jolt to the idea that we are special in the cosmos. If, on the other hand, we learn that there is only one Universe, and we get some details on the causes of the Big Bang, those details could strong affect how people think about what they should do with their lives.

Do you think we can ever travel close to the speed of light for space travel with our current pace in tech advancement?

OurLordStan

Yes. But one of the biggest limitations in approaching the speed of light is not our technology, but our bodies. The speed of light is very high, and to get close to it, you need to accelerate. You can do that very quickly if you have powerful rockets, but there's a limit to how much acceleration a human can tolerate. Even fighter pilots can only take 10g for brief periods, and at that rate it would take a looooooong time to get near the speed of light. Accelerating at 1g would be comfortable, but would take even longer. So perhaps we need to develop some of those cool acceleration couches they have in sci-fi novels that let humans survive 100g acceleration!

Why do the 1/3 and 2/3 charges on quarks exactly balance the 1.0 charge on an electron... a completely unrelated particle..... and allow atoms to form?

colinha

Awesome question! It seems like a crazy coincidence right?

In our current theory, these charges are unrelated, meaning that they could be different and the theory would still work.
So, either (a) it's a huge coincidence or (b) it's a clue.

If it's a coincidence, then it's a super-extra-double-huge coincidence because it's EXACT. These charges are not just close to each other, they balance exactly. It's not a coincidence like the way the Sun and the Moon are ~the same size in the sky, it's much more precise.

It could definitely be a clue that there is a deeper layer of reality underneath. It would make a lot of sense if the quarks and the leptons were both built out of the same kind of smaller particle. But, so far we have no hard evidence to support that idea.

I don't like the anthropic argument ("if it wasn't like this we wouldn't be here to ask the question") because it closes the door to further study and exploration. I think the point of asking Big Fat Juicy Questions About the Universe is to look for answers, not to throw up our hands and shrug.

What unanswered questions do you think can NOT be answered, assuming no unforeseen technological/scientific revolutions?

Mazzelaarder

There are a lot of questions that cannot be answered by science. For example: what should I do today? Should I eat that 2nd cookie? What is it like to be a bat?

Science can only answer questions about things that can be experimentally tested. So that means that there are more serious questions that we still can't answer with science, like: What is outside of the observable universe? Are there completely undetectable forms of matter?

Because we have no way to observe or detect those things, there's no way we can get hard answers about them.

So there are lots of limits to what kinds of questions we can get answers to.

And then there are very reasonable questions: what is the smallest particle? What happened before the big bang? Right now we don't have the tools to answer them, but the important thing is to ask them, and try to work on developing new powerful scientific instruments to crack them open!

Hi guys! I have a question for Jorge

As many places are, my grad school department was plastered with PhD comics. You have real insight into the human part of what it means to go through training in the sciences. You've been at this a long time now, I know you were already well established when I started my PhD 8years ago. I know you've moved into creative projects like this one full time.

My question: How do you keep in touch with academics and their experience as you get farther and farther away from grad school?

superhelical

You mean, how deep are the scars? They run deep. Kidding aside, PHD Comics has never really been about me. It's always been (and hopefully continues to be) a channel for everybody's experience in

academia, so it's very much powered by the suggestions people write in, or the conversations I have when I visit schools.

What's your take on string theory? What progress has been made? Is it generally accepted that we live in 12 dimensions?

It seems people like Michio Kaku and Lawrence Krauss are convinced we live in a 12 dimensional space with infinite universes..is string theory that solid?

FuckLife9988

String theory is a mathematically beautiful theory which has the potential to answer a lot of deep questions about the Universe.

But (and this is a huuuuge but) so far it is not really testable. We can't tell if it's more than elegant mathematics unless it makes predictions about experiments that we can do. So far, it deals with objects that are 10^{10} times smaller than anything we can probe, so we cannot validate or invalidate it. That means that it's not really a scientific hypothesis yet. Note: that doesn't mean we should abandon it, it just means we need more powerful tools and more work to come up with ways to test it!

What is your opinion on the One-electron universe theory ?

SkillzTom

My opinion is that this is a super fun theory, and I'd like to spend an evening smoking banana peels and discussing it further.

But, beyond that, it seems a bit outside the bounds of science. One of the points we try to make in the book is that it's really cool that there are questions in the Universe that are really BIG questions but that are also science questions: questions with a firm answer that we can learn by doing experiments.

For the one-electron theory: can you imagine a science experiment you could do to test this theory?

If you could change just one thing in the universe (intelligent design style), what would you change?

hotpotato70

I would make the speed of light much faster, so that we could see further into the Universe, and communicate with neighboring star systems more quickly.

What questions do you hope are never answered?

I always hope the human race has something to strive for.

Lil-Lanata

I hope that all of our questions are answered! I would loooove to know the answers, and the fun thing is that the answers exist, they are out there waiting for us.

Don't worry about running out of questions: so far, every answer has generate more questions, and as long as humans are alive there will be curious people asking more, larger, deeper questions!

Is the number of unanswered questions increasing or decreasing?

ollehar

Increasing, for sure!

Because humans are curious creatures, every time we learn something about the Universe, it creates twice as many questions.

Don't take that to be discouraging: asking questions is what makes it fun to be alive, and it would be strange to live in a world that we totally understood.

I've watched dozens of videos and documentaries regarding what particles, fields, and waves are. I have a solid grasp on the science associated with them, but it's extremely difficult to actually visualize them in my mind because a lot of the illustrations in the various educational mediums are either old and now immaculate or simply condescending to the science. Do you know of any material that visualizes sub-atomic physics according to our current understanding.

Watermelllons

Great question!

The problem is that you are trying to understand something new in terms of things you understand. That's totally normal, and that's a classic strategy, but it doesn't work here. Particles are not little spinning balls of matter, and they are not just waves, they are something weird and totally alien to our experience. So we can use these ideas (particles, waves) to try to connect them to things that we DO have an intuition for, but it can never be completely accurate, because reality at the quantum scale is very different from anything we have experience with.

In the end, you have to put aside your intuition and rely on the mathematics to guide you.

I love your comic! Thank you for doing this AMA :)

Few questions:

What do you think is the probability we'll find life, or evidence of past life, on another planet in our lifetime?

What's getting a PhD like?

I've always wanted to go into higher academia but never felt smart enough, curious what a day in the life of a PhD is like!

BlueSky1877

About finding life: I'm amazed at the progress we have made in discovering Earth-like planets, and new telescopes will be able to soon tell us about their atmospheres. So it's not impossible!

Getting a PhD: I had a great time getting my PhD and the rest of my academic career. A lot of people struggle with the uncertainty and job prospects, which can be hard. My advice is to make sure you are doing something you enjoy, so that even if it doesn't lead to a faculty position you still got something out of it. Don't suffer and struggle for the promise of future rewards.

Where does a photons energy go when it is red-shifted via the Doppler effect and where does a photon get its energy from blue shifting? And if your answer is that the red-shifting and blue-shifting cancel out, consider a system where a light bulb is placed with a conical mirror placed behind it, so the majority of the light goes in one direction.

aaRecessive

Great question! I love that you're thinking about this and trying to reconcile two physical effects.

The photons energy doesn't go anywhere, but the wavelength that you think it has depends on YOUR velocity.

It's hard to think about photons, so think about a simpler case: your car. If you are driving at 80 mph on the highway, then a police car parked on the shoulder sees you moving with a lot of energy. But someone driving next to you at the same speed measures your relative speed to be zero. Where does your energy go? Nowhere, it's just that your kinetic energy (which depends on your velocity) depends on the velocity of the person doing the measurement. In the same way, the wavelength of the photon depends on the velocity of the observer. That's why we use it to measure velocities.

What is the next big discovery CERN expects to make?

j938920

Great question, I wish I knew!

But there are two broad categories: things we anticipate and things that we don't.

Things we anticipate: a lot of people are hoping that we will discovery supersymmetry, which would be a whole new set of particles that mirror the existing particles. If it's discovered, it would help theorists understand some strange features of our current theory, like why the Higgs boson is not super duper heavy (see my answer to another Q about that). But so far there are no hints of that. There are other things people are looking for: dark matter, gravitons, etc. No hints there either.

Things we don't anticipate: Theorists are very good at thinking up new ideas, but I suspect that the True Theory of Nature is not one that's currently sitting in the grey matter of any human theorist. So, we need to do more than just check the boxes of current ideas, we need to treat it like an exploration of new territory. When you land on an alien planet, you don't just limit yourself to look for one kind of life (yellow roses), you try to explore broadly and look for anything new and interesting. So some of us at the LHC are trying to make sure we look under all of the rocks, and we are hoping that something weird pops out at us!

What would be the broad characteristics of a future, not yet created, technology that would help to answer some of these questions?

Sir_Wemblesworth

Some of these questions just need improved scientific instruments: more powerful particle colliders, larger space telescopes.

In a lot of cases, we can literally BUY the answers by building these tools. We know how to build them, but science funding is limited.

Is only me came here and expecting every answer to be "WE HAVE NO IDEA"?

funelite

You have the right idea!

But even if we don't know the answers, it's a lot of fun to explore the questions, because they tell us where to look and what to think about.

True randomness, Bell's Theorem, superdeterminism and free will. Einstein said that god does not play dice. Experiments and prevailing theories in quantum mechanics seem to suggest randomness exists, but we may be measuring incompletely.

What are your thoughts on true randomness and ultimately free will? Is it even possible to know?

EverythingIsFractal

Experiments support the true randomness of the Universe at the quantum scale. The question of free will is one that is difficult to pose in a scientific manner, because it's entangled with the question of consciousness. See my reply on that question.

What is the successor to the LHC going to be able to do for you and how much is it going to cost to build it?

Also, can I come work for you guys even though I don't know enough physics to light a bunsen burner?

AbulurdBoniface

There are plans for a 100 TeV collider (~10 times the LHC energy) which could probe matter to smaller scales.

Every time we build a collider with more energy, we are exploring virgin territory, we are examining a region of the Universe that no human has ever before seen. It's like landing on a new planet.

So if you increase the energy by 10x, then you are opening up the space of exploration by a factor of 10. It's like simultaneously landing on 10 earth-like planets. Wow!

How much will it cost? A lot. A LOT.

If you want to do particle physics, the first thing to do is to learn to program. Then find your nearest University and go join their group!

Hi Jorge,

I'm a PhD student who is going to submit my Dissertation to my committee later today! Any advice on how to handle the following few days as I await my inevitable doom?

its-fewer-not-less

Hmm, I'd recommend distracting yourself with a good book, perhaps one about the big mysteries of the Universe (hint hint).

How about the question: Why is there only one type of mitochondria? There are more bacterial inclusions in cells that still carry their own DNA, but of mitochondria, the electricity supplies of cells, enabling all multi celled life, there is but one type. All plants and animals share it. Why aren't there more variants, like with the chlorophyll in plant cells? What made this one so successful that it has ever mos, grass, human and whale as it's offspring? Was the inclusion such a rare event that we should't expect multi celled organisms on other planets?

d-a-v-e-

Great question! It's a bit far out of our area of expertise, unfortunately. We will ask our biologist friends and let you know.

Which (upcoming or not) answers are you most looking forward to?

Mazzelaarder

I'm looking forward to answers that completely upend our ideas of the Universe. This has happened repeatedly in history: heliocentrism, relativity, quantum mechanics, dark matter, dark energy. We keep discovering that our view of the Universe is based on our unrepresentative experience, and that things work VERY differently than we imagined.

Currently, we know that we know very little about the Universe, so we are fairly certain that there are big mind-blowing discoveries awaiting us. I can't wait to hear what they are, but of course it's hard to know in advance where they will come from. That's why its important to ask these questions!

Which (upcoming or not) answers are you most looking forward to?

Mazzelaarder

I'm looking forward to being totally surprised and blown away at revolutionary discoveries which I hope are around the corner. Most of the deepest discoveries in physics have been surprises or accidents, and so they were very difficult to anticipate.

Dark Matter seems to be an easy way to explain puzzling astronomical observations.

Are there others theories who picked up steam recently ?

MyrLeaf

There are a few other possibilities, but none of them do a great job of describing the data we have collected.

But within dark matter, there are lots of possibilities remaining for new ideas: what IS the dark matter? Is it one kind of boring particle? Or lots of different particles? Or some new kind of matter entirely?

What serious current theories would sound the most preposterous to an average person?

know_limits

I looove this question, because it recognizes that these science questions have important personal and

philosophical implications. That's why we wrote this book, because these questions impact everyone, and unlike some philosophy questions, they actually have hard answers that we can learn!

I think that learning about how the Universe began would really affect how people think about the human situation. If we learn that our Universe is one of an infinite number of Universes, then it's another jolt to the idea that we are special in the cosmos. If, on the other hand, we learn that there is only one Universe, and we get some details on the causes of the Big Bang, those details could strong affect how people think about what they should do with their lives.

What is your favorite dark matter candidate and why?

SmashBusters

My favorite outcome would be to discover that DM is not anything that is currently theorized, but something totally new and different that upends our understanding of matter completely.

If you have no idea, then what is there to ask?

seal-team-lolis

We have lots of big questions about the Universe that we want answered: what are things made of, how did things begin?

But we (currently) have nod idea what the ANSWERS are!

Hi and thank you for this AMA. My question is a personal one. What is your personal view on what our universe is? Is it a multiverse? Are we trapped in another universes black hole? Are we a computer program, or a hologram? What are your thoughts?

FairlyDinkum

These are all fun ideas, but currently we don't have any reason to believe one theory or the other. But keep thinking and asking these questions!

Are you planning on translate the book in other languages? (like italian, pls?)

Voveve

Yes, there are 15 different translations being prepared!

Thanks for the AmA Sir

Greetings from India

My question would be how you will define what exactly is time, space and gravity?

Prabir007

Wow, so many questions in one!

Time: my view of time is that it's what connects a series of snapshots of the universe together. But we

don't know much about why we have it: why can we only move forward in time?

Space: we know that space is more than an empty backdrop, because it can jiggle and bend and expand. But what IS it? We don't know yet.

Gravity: this is a real puzzle, because while general relativity tells us that it's the bending of space, quantum theory suggests that all forces should be mediated by tiny particles. So we have to find a way to bring these two ideas together.

What's the *smallest* unanswered question in the universe?

Taneb

There are a lot of fun questions about what is the smallest thing in the Universe: is there a smallest particle, or can you divide matter an infinite number of times into smaller and smaller particles?

Does quantum theory give us any insight into the nature of consciousness, or is any alleged connection there demonstrably hocus-pocus?

sunshinehyperbole

The nature of consciousness is a very interesting, very important problem, but in my opinion one that may be outside the realm of scientific inquiry. The reason is that science requires an observer, and theories of consciousness require us to step outside of the observer and ask questions about the observer. But we cannot do this -- there is no way to observe the observer without having the same biases as the observer.

I'm so excited to see this AMA! I binge read the comics last summer, and I got my copy of the book two days ago. I really love the comics and the videos.

I am an Astrophysics undergrad and in our last intro lecture two weeks ago we barely scratched the surface of particle physics. This semester of physics made radioactive decay much easier to understand than I thought it would be, but I do wonder about the proton - specifically I am curious what makes it so different that it can decay through beta+ decay, but not on its own. I've read that we don't fully understand the proton. What theories are being investigated?

If I may, one more - I am actually a nontraditional student who returned to school at 35 after my two kids were in school full time, and switched from a very different field. Dr Whiteson, do you have any colleagues who took a less traditional path and have been able to become productive members of the physics community? Do you have any advice about how an older student can play up the age difference in a positive way in graduate school applications?

Thank you!

Seluine

Hi,

Yes, plenty of people have returned to academia as older students. You have an advantage in your maturity, because you are organized and have a better grasp of what you want in life. Try to let that come through in your applications.

Good luck!

1) Why should I buy your book vs. The book by the guys who reckon they have some idea?

2) Can the LHC please hurry up and destroy the world after 2016 I think we're all just about done here.

just__peeking

1) Our book has cartoons in it

2) No.

What is the closest thing to an alien life form that accepted by science community?

ahboyd15

I'm not aware of any!

Assuming our Universe is finite and accelerating in its expansion what would the edge of the universe *look* like? Would the expansion of the universe itself, at these edges, have to be travelling at the speed of light since otherwise that would mean a paradox is taking place in which light has reached outside our universe? When considering what this actual "edge" is, how would you characterize it when talking about the universe expanding?

Ghawr

Hi,

Great questions, and hard to answer briefly. There are two chapters about this in the book, so take a look for more details.

In short: we don't know if the Universe is infinite or has an edge. If it has an edge, what would that look like? It could be that the edges are connected, so the Universe curves back on itself. Or there could be a true edge, though that would be bizarre to us.

Recall also that while we can't travel THROUGH space faster than the speed of light, there's no limit to how fast space itself can expand!

For the CERN Particle Physicist (Daniel Whiteson).

Can the an electron even come close or exceed the speed of light?

Darwinism21

Hello!

Electrons can approach the speed of light, but they can never reach it because they have mass. And nothing can exceed it!

We can't really see far into the universe, who's blocking our view, and what do they want?

hotpotato70

Actually, the Universe is remarkably transparent to visible light, which is why we can see so deeply into the Universe. What limits us is the speed of light. Some things are so far away that the light from them hasn't had a chance to reach us yet!

The Mandela Effect is real. Why are scientists willing to speculate about multiverses and dimensions and stuff but are ignoring the thousands of us who remember a whole different reality?

We aren't just ignored but mocked and threatened. Why?

It was Sex In the City, 4 people in JFK 's limo, Depends underwear, Curious George had a tail, the North Pole was shown on globes and maps, Isaiah 11:6 was the lion laid down with the lamb not the wolf like every bible says now, etc.

There is also a ton of evidence but not one scientist is talking about this publicly. Why?

Edit: And it dang sure was Bernstein Bears, then Berenstein Bears, now Berenstain Bears. We all know it.

DagneyColeman

It's certainly likely that there are things in the Universe that make little sense to us. Some of these things (dark energy) are real but unexplained. Others (string theory) are plausible but not testable. Another category are the bizarre. Fun to think about but hard to grapple with scientifically.

If I could look through the Hubble telescope at the most distant star and instantly be able to locate myself to that star - where would I be my address in the oberservable universe ?

Is it arbitrary ? And if I keep on doing that same thing (ie warping myself to the further observable star) would I eventually make progress by getting into non-observable universe (from earth) - or is this just a theoretical concept that is physically impossible to get to ?

How does it work in relation to the balloon example ? Where is earth and where is the furthest star ? (I get that the stars are probably burnt out by the time the light gets to me)

tyson2017a1

There is an edge to the observable universe but there's no way to transport yourself there instantly. Once you try that you are outside the realm of the real. But it's fun to think about!!

Hello everyone, this question is more directed at Daniel Whiteson but I ask anyone with any opinion to answer:

This might be a ridiculous question, I don't know, but, do you think that we are unable to surpass the speed of light due to a space-time wave-front generated in front of matter traveling at any velocity, not unlike a sound barrier in front of a fast moving jet?

I have a theory that the nature of space-time is such that we do not have enough energy (perhaps in all of our universe) to poke through this space-time barrier.

If there is any recommended literature that you know of this topic it would be much appreciated! Thank you.

jumpinjahosafa

What kind of wave-front are you imagining? Waves in space-time are generated by accelerating masses, yes (see gravitational waves) but they do not produce a speed limit.

Hi, Daniel-

I'm a new particle physics grad student on ATLAS and I'm currently dipping my toe into some mono-H stuff, which I know you've worked on a bunch. In one of your theory papers on the topic from a few years back (https://arxiv.org/abs/1312.2592), one of the dark matter models you consider is one with a massive vector mediator that gets its mass from a new baryonic Higgs. You mention in the paper that this could lead to new stable SM-neutral baryons, which would be good dark matter candidates. My question, though- haven't a lot of the cosmic microwave background measurements effectively ruled out baryonic dark matter?

Thanks!

StopSquark

Great question. Yes, that theory has a baryonic Higgs, but it doesn't mean that the DM would be made of those Higgses. There would still be a neutral fermion for DM.

What would happen if there was a pebble at rest in zero gravity and an object with twice the mass collided with it? Would there be a perfect inelastic collision? Seeing that there is no friction, would the final velocity of the two objects be lower or constant?

That is: MoVo + MpVp = MtVo ? Where Mo is mass of object that is twice mass of pebble

Where Mp is mass of pebble

Where Mt is total mass.

Thank you for your response. I look forward to it!

Flamingskullion

Are you trying to get us to do your homework for you? :)

What happens if two universes collide?

hotpotato70

Boom.

Seriously, it depends on what you mean by "Universe". If you mean everything that exists, then the question has no meaning. If you refer to "pocket universes" created during Inflation, then colliding universes would look just like colliding galaxies do in our Universe. See the "Bullet Cluster" for examples.

What are your thoughts on the fourth dimension and how do you think we can interact with it in a meaningful way? When do you think this might be?

Arrow_King

Actually, there's a whole chapter in the book on extra dimensions. People typically refer to time as the "fourth dimension". We sort of "move through" it in the same way that we move through regular space (some theories even refer to spacetime as one thing), but with some important differences that tell us it's not the same thing: We can't go back and forth in time, only in one direction; and we can only go through it at one speed: one second per second. If there are other dimensions, physicists think they are really small and form little loops, and the only way we'd detect them is by seeing particles get "heavier" as they vibrate in these tiny dimensions. -Jorge

What exactly are the primary reasons that our universe (or maybe more the matter consisting of it) can't be a cyclical process?

kavono

It could be a cyclical process.

Currently, the Universe is expanding due to dark energy. But since we don't know what dark energy is or what processes control it, it's POSSIBLE that it could change course and collapse the Universe. But we have no idea!

Which comics do you feel are your most wholesome Ph.D. comics?

phd_dude

All my comics are pretty G or PG rated. This is probably the most indecent comic I've done.

HOWEVER, in our new book we do talk a lot about Black Holes and Big Bangs.

My question requires a brief thought experiment. Start by imagining that there is a vast number of different sized systems, both smaller than what is currently detectable and vastly larger than our known universe, or even theoretic multiverse. Now, use a system currently within a scale that we comprehend as a framework for explaining concepts that maybe prevalent on either side of the spectrum of unknown sized systems. In this case, we'll use the system of a cell to relate to. The cell as a whole abides by natural physical laws, yet within a cell, different mechanisms govern different functions. All the structures inside of the cell are bound by the cell the cell wall, so that as the cell evolves, the mechanism within are affected but they also adhere to their own respective functions. Now, compare the cell's structures to our universe, and the cell wall to correspond with an outer "boundary."

My question is, could we relate dark energy and dark matter to a vastly larger sized governing system, whereas presence of a larger scale's physical laws can impact the systems within? thus allowing the physical laws of our universe to function while also being influenced by the exceedingly larger system. Just as a a cell is influenced by its outside system, yet each structure, or organelle, within the cell still functions according to it's respective duty, or governing law. So that dark energy would be due to the expansion of an outer "boundary" of our universe and dark matter could possibly be a medium contained within the outer "boundary;" influencing our universe yet undetectable to us because of the vast difference in the size and scale of different systems and also due to the limited interactions between physical governing laws.

TLDR: basically, could dark energy be a force due to an expanding "outer shell" of a system that our universe, and possibly others, are contained within?

Bethanyblair

The truth is that we know almost nothing about what dark energy is. So we need people thinking creatively about it, like you are!

Are there currently any unexplained candidates for alien superstructures?

scottcmu

Not that we know of!

Ask anything you say? Very well, i will crosspost from r/askscience then since i love your work and your areas of expertise (most Dan's. Sorry Jorge!) are relevant.

Im an amateur game designer working on a Tabletop science fiction RPG. Think something like Mass Effect meets Firefly.

Now, i come to you today not to ask about the crazy space physics of warp travel and all that. I've come to accept that that is one of those things that i will need to simply handwave, while injecting as much theoretical physics as i can research that supports my FTL system. What i come to ask you about today is technology we currently have, and so its a bit more quantifiable.

Beams. Specifically, LASER and MASER weaponry.

I fully understand and accept that as long as humanity can throw small objects at each other at extreme speed, that will likely be the optimal method of warfare (indeed, railguns and traditional ballistic weaponry are the most common weapons in the setting for this reason) but for story reasons, it is important that beam weaponry exists even if it isnt as efficient as projectiles.

My question is thus- is there a way to make a beam weapon that would be on the visible spectrum while also being a lethal weapon, within reasonable distances? So far all i can come up with is to have a laser weapon that modulates into a visible frequency every fraction of a second for the same reason modern militaries load a tracer round every fifth cartridge in a mag.

Does that make any sense from a science perspective? Is there a better option? Though im okay with handwaving a few things like warp travel im trying hard to make the majority of the universe actually make sense from a physics / engineering standpoint.

Thanks in advance

JustAnotherBusyDrone

I don't know much about laser weapons. Honestly one reason that i got into particle physics is because it has almost no easily weaponizable applications and so avoids a lot of the immediate moral ambiguity of other fields of physics.

Hi Jorge,

this may be an odd question, but I'd genuinely like to hear your opinion: How do you feel that you work (wi´hich I love, by the way) is featured in the "Stanford authors" section of the Stanford Bookstore, yet John Steinbeck is missing completely. As is *any* reminder of his six years on the farm, only thing I saw was a portrait in the Nobel Laureates Gallery somewhere in the faculty club. I found this *very* odd, maybe you have some insight.

ssatyd

That is definitely odd! He spent more time there than me!

I'm too shy to ask a question, for fear of looking silly, but I just want to tell you that as a layperson, the subject of your research fascinates me. I'm deeply curious about the research done at CERN and the subject of dark matter especially fascinates me. Your book looks great, perfect for regular people like me who want to know more, explained in a way that I can understand. I'll be buying it!

OriginalClownHerpes

Hope you enjoy it, and if you have questions later you can send them to me @DanielWhiteson on twitter!

Why does my wife not love me anymore?

Gerden

Too much time on Reddit?

Ok, I love this stuff. Are you trying to explain this level stuff to normal people? How are you testing its comprehensiveness? Because most physics for dummies books are to dense for the average person. Would my acountant mother understand black matter after reading this?

111omnipotent

We did our best to make it totally accessible. Give it a ready and let us know!

Thanks for continuing to work in science outreach, both of you!

I'm a PhD student, and I'm increasingly concerned that there's a segment of our population who claim to be anti-science. I say 'claim' because in my experience most of these people enjoy a lot of benefits from gains in research without realizing it - but continue to loudly rail against their idea of what science represents (mainly green energy research and climate science). How do you communicate scientific ideas to someone who considers themselves anti-science?

Thanks!

curruogh

I think the first thing is to admit that Science doesn't have all the answers. After that, it's important to make the argument that while Science isn't perfect, it's still the best method for knowing what is true or not. The alternative to science is to make stuff up, which doesn't seem like a reasonable way to go about doing things. -Jorge

Thanks for continuing to work in science outreach, both of you!

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ideas to someone who considers themselves anti-science?

Thanks!

curruogh

Hello!

Good points, for sure.

Our approach is to try to touch on the nerve of human curiosity that we all have. If we can convince people that these questions are interesting and fun, then maybe they can understand why we want to do science: explore the unknown universe!

I was recently talking to a few professors about the march for science a few weeks back and had a few questions that I feel were addressed rather weakly.

What are your thoughts on how to promote evidence based science/research in an age where the internet has made it more easy to virally spread conspiracy theories and pseudo science?

Is there anything us scientists can do about it?

Also, I'm going to wrap up my PhD rather soon. Jorge, thanks for providing lots of laughs throughout my grad school career. Appreciate you swinging by our campus a year or two back and giving us a free screening of the PhD movie!

bigtcm

I think it's important to communicate to people why we are doing science by touching on the common human nerve: curiosity. If we can remind people that we all care about the answers, then maybe they can understand why what we do is important.

Red blood cells help body, other things do other stuff, there's entire universe of living organisms inside each of us, and they know how to do their specific thing, though some fail and degenerate.

How do we know that we're not just microorganisms inside a much bigger sentient being who'd consider each of us not significantly smarter than a red blood cell.

hotpotato70

Right. You could even consider our society as some kind of super-organism. Or all of humanity.

How do you have an idea of the amount of things you don't know? (As pictured in the graph)

truth_sentinell

There are several ways we know how much Dark Matter and Dark Energy there is relative to regular normal matter. The amazing thing is that they all agree, so physicists are fairly sure the graph is accurate. We cover them in the book, but here is a brief summary: a) from the patterns of the Cosmic Microwave Background (the "baby picture" of the Universe); b) from the rate of expansion of the Universe and c) from the current structure of galaxies and galaxy clusters.

The problem is that we have no idea what Dark Matter and Dark Energy are, we just know that they are there. It's like we live in an era of precision ignorance. -Jorge

How do you have an idea of the amount of things you don't know? (As pictured in the graph)

truth_sentinell

In general, we cannot know how many things we don't know.

The graph represents the energy budget of the Universe: 5% matter, 27% dark matter, 68% dark energy. It's just one way to think about how much we don't know.

Do you think tachyon based time travel is possible like in Land of the Lost?

Pussyslayer42069

Unfortunately, it seems like time travel is impossible! Going backwards in time would violate causality (cause and effect).

First of all thanks for doing this AMA!

My question to you is, what is the status of all the candidate theories for TOE?

My second question is, should I pursue physics undergrad next year? Is there scope in research (theoretical)?

rusty_ballsack_42

Hello,

Great question, but hard to answer in this small a space. Read the chapter on that in our book! Briefly: there are lots of fun ideas, but none are complete and none can really be tested yet.

Should you do physics? If you love it, then follow your dreams. There are a lot of fun directions to explore.

Do you entertain the idea that we are living in a simulation?

Jorow99

Yes, it's an entertaining idea!

Electromagnetism, do we understand it thoroughly? What is something that is still up in the air?

Did we find evidence for monopoles? And if we ever, how such a discovery could shape the current science?

What is one thing you like to see invented? What are the applications of electromagnetism we can use in consumer world that we are not already using?

NonElectricalNemesis

There is no evidence for magnetic monopoles yet, and if we found them then it would help us understand why electric charge seems to be quantized.

What is the answer to life, the universe and everything?

GreekYoghurtSothoth

42, of course.

What undergraduate degree will help me get a PhD in Robotics? I'm studying Computer Science right now, with a goal of a robotics PhD specializing in machine learning. Should I be doing Computer Engineering or Electronic Engineering instead? There are no universities with undergraduate programs in robotics that I have access to.

mghoffmann

Computer Science is probably your best bet out of the three. Make sure you take some courses in mechatronics.

Do you think we will ever have an effective system for observation of fundamental particles that will allow us to directly test theories like string or m-theory without relying on pure mathematics and interpolation?

Follow up: Do you like your gravity loopy or stringy?

CicerosGhost

I hope so!

Using current technologies it would be suuuuuuu-uu-uu-uuuuuper expensive. So let's hope we can invent more efficient or powerful particle accelerators!

Why is the universe finite? What comes "after" it? Also, why did the universe begin? I think that one's probably the most interesting question to me because there's obviously no way to have causation if there's nothing before it, but that would imply that it's always existed.

nv-vn

We don't know if the Universe is finite or infinite. I wish I could give you a longer answer, but we have a whole chapter on that in this book!

How would you disprove a flat earther?

Langstaffio

Quick trip to space?

Will be there any changes to the current Big Bang theory if the Black Hole theory is proved incorrect?

shohamc1

One current problem with the Big Bang is that we don't understand what happens when a lot of matter

is squeezed into a tiny distance, because both general relativity and quantum mech have something to say, and they don't agree. So understanding black holes might help us understand the early universe!

If a thing outside our universe could pick up and shake our universe, would we feel it? Or since we're just relative to other things inside, we'd be fine?

hotpotato70

Depends on what you mean by "outside our universe". If it can shake us then it can interact with us and it's part of our universe, no?

And there is a real thing that's doing more than shaking the universe: dark energy is tearing the universe apart!

Do you also consider topics from the life sciences to be included in your book? E.g., how life began, what other life types of life form can exists..?

PhDinGent

We have a whole chapter on the possibility of life outside the planet Earth. Such a possibility depends on whether the events that led to life on Earth are rare or super common. Unfortunately, we only have one data point so far, and that's us! -Jorge

Hi to both of you!

Have any new experiments been run to test/verify the theory of the Higgs field, or is it just our best guess right now?

gambiter

Hello back to you!

Yes, we are certain that the Higgs boson exists, which proves the existence of the Higgs field. But there are still a lot of questions about what kind of Higgs it is -- and there are quite a few theories that we are testing!

How did Daniel manage to get a job at CERN? It's been a goal of mine for a few years, and I'm kind of lost as to how you would even go about applying, much less getting a job there.

DJKokaKola

This is Daniel. I don't work for CERN directly; I'm a professor in the US and use CERN as a laboratory for research. Lots of people from Universities around the world use their world-class facilities!

What are your personal theories on what dark matter is, if you were to hazard a guess? Like, if you were writing a sci-fi story that deals with dark matter, what fictional properties would it have?

wonkothesane13

I would make it not boring. Like some new kind of weird matter we have never seen before, not just a

heavy neutral particle.

What is your opinion on time travel? Has your research with the LHC yet produced any black holes? Can human consciousness be compressed down to 36 bytes? Is the big screen CRT TV downstairs on?

El...Psy...Kongroo...

skeetsauce42

Time travel: only possible forwards. Black holes: not yet Consciousness compression: I hope not!

What happens when you enlarging a electron if you consider quantum physics? (And please for the love of everything don't try it) I was just curious if you had a hypothetical answers because apparently it would rip a tear in time?

alexthecrazy247

In our current theories, an electron is a point particle: it has zero volume.

I absolutely hate inflationary cosmologies, the very concept seems entirely unphysical. Have you looked in to any cosmologies that do not require inflation?

Nukatha

There are some, but they have a hard time explaining some of the puzzles that inflation answers, like the horizon problem and the smoothness problem.

This one is for you, Daniel!

How would one attempt to prove the existence of tachyons?

I think we could all benefit from a tachyonic antitelephone.

NonchalantWalrus

Tachyons would violate causality, so I don't think they are possible. Too bad, though, I'd love that phone!

How is a wormhole made and what exactly do they do?

ChilledTerror

A wormhole is a connection between two points in space that would otherwise be distant.

How to make them would require a longer explanation, and massive amounts of energy!

Do you think we as humans will figure out a lot of these answers before the extinction of the human race? If so, will these answers help in preserving our race?

roadhouse21

We have no idea, but we hope so, and we are doing our best.

Are there any legitimate fears to the consequences of testing LHC and how much we don't know currently about particles physics?

tahni_stacks

No. Collisions at much higher energies happen all the time when cosmic rays hit the Earth.