Science AMA Series: In 1915, Einstein published his general theory of relativity. How are scientists using Einstein's theory today? We cover physics and astronomy for Science News. Ask us anything!

Science_News[1] and r/ScienceAMAs[1]

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Abstract

Hi reddit! We are the astronomy and physics writers for Science News (https://www.sciencenews.org/), a publication of the Society for Science and the Public (https://www.societyforscience.org/). This November marks the 100-year anniversary of Einstein's General Theory of Relativity. To celebrate, we published a special issue of Science News focusing on how researchers are using Einstein's theory today–from using it to magnify the cosmos to exploring quantum entanglement. About Andrew Grant: I am an award-winning physics writer for Science News. I have a bachelor's degree in physics from The College of New Jersey and a master's in journalism from New York University's Science, Health and Environmental Reporting Program. My story ("Entanglement: Gravity's long-distance connection": https://www.sciencenews.org/article/entanglement-gravitys-long-distance-connection) examines a big idea to expand the scope of general relativity that involves black holes, wormholes, holograms and a mysterious phenomenon called quantum entanglement. Physicists are exploring whether long-distance quantum connections are responsible for the geometry of space and time in the universe. About Christopher Crockett: I am the astronomy writer for Science News. I received by Ph.D. in astronomy from the University of California, Los Angeles. After eight years of searching for exoplanets, probing distant galaxies and exploring comets, I realized I enjoyed talking about astronomy a lot more than actually doing it. After being awarded a 2013 AAAS Mass Media Fellowship to write for Scientific American, I left a research career at the U.S. Naval Observatory to pursue a new life writing about anything and everything within the local cosmological horizon. I joined Science News in early 2014. My story ("Using general relativity to magnify the cosmos": https://www.sciencenews.org/article/using-general-relativity-magnify-cosmos?mode=pick&context=163) explores how scientists exploit phenomena predicted by the general theory of relativity to study the universe. We here to answer your questions about Einstein's General Theory of Relativity and how scientists are using it today! We'll be back at 2pm ET (11am PT) to answer your questions! Ask us anything! EDIT: Thanks for the awesome questions! We had a blast. We'll be checking in throughout the day to answer more questions. Until next time!

the
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REDDIT

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SCIENCE_NEWS R/SCIENCE

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READ REVIEWS

WRITE A REVIEW

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One of my favorites to ask:

How is the battle to the reconcile the theory of relativity and quantum mechanics going?

Paradigm6790

It’s actually a very encouraging time (especially for someone like me watching from the sidelines!). Einstein brilliantly figured out how gravity works by formulating the curved fabric of spacetime. But where does that fabric come from? That’s what physicists are exploring now. The most tantalizing possibility is that entanglement – a strange quantum bond between particles – shapes spacetime. See my recent feature on this: https://www.sciencenews.org/article/entanglement-gravitys-long-distance-connection. -AG

What is your favourite solution to the Einstein field equations?

Do you think acoustic black holes, like in fluid systems or Bose-Einstein condensates, will be a neat way to learn more about general relativity, or just something cool?

iorgfeflkd

I like the one that allows the Road Runner to slap down a black decal that opens up a pit in which Wile

E. Coyote can fall. As Einstein intended, I imagine.

But honorable mention should go to a solution known as the Friedmann–Lemaître–Robertson–Walker metric (or FLRW to its friends). It's basically what all modern cosmology is based on — it summarizes the "big picture" history of the universe in just a couple of equations.

FLRW is what you get if you assume the universe is homogenous (the same everywhere you go) and isotropic (the same in every direction you look). Out of this equation (and a few that can be derived from it) you can piece together some of the greatest hits of 20th century cosmology: the expansion of the universe, the age of the universe, dark matter, dark energy. When cosmologists determine the age of the universe, what they're actually doing is measuring things like the density of matter (both normal and dark), dark energy, etc, and then plugging those values into these equations to get an age.

In short, FLRW is probably one of the most important equations you (or most people) haven't heard of. –CC

What is your favourite solution to the Einstein field equations?

Do you think acoustic black holes, like in fluid systems or Bose-Einstein condensates, will be a neat way to learn more about general relativity, or just something cool?

iorgfeflkd

Is this a question you ask at cocktail parties? I'm going to go with Schwarzschild's. He came up with it really quickly, and it led to the idea that black holes exist!

I think making analog black holes is really interesting. I wrote about one recently: https://www.sciencenews.org/article/hawking-radiation-spotted-within-sonic-black-hole. Would observing some weird phenomenon that occurs near a black hole of sound mean that the same thing happens near a real black hole? No, but it could give physicists some ideas and strengthen the already strong case for Hawking radiation: Stephen Hawking's idea that black holes will eventually evaporate. -AG

How far behind would we be without Einstein's theory of relativity? Or if it was only discovered years later? Plus, some scientists are trying to prove Einstein wrong. What are they trying to prove? Edit: I asked something different from what i meant. When i asked what scientists we proving wrong about Einstein i meant what they were doing to correct his theory from small mistakes.

resspt

Yeah, I'm not a fan of the whole "let's prove Einstein wrong" thing. We know general relativity describes the universe beautifully. But we also know there's more to the story. GR breaks down at the small scales governed by quantum mechanics, which is why physicists want to formulate a theory of quantum gravity. For physicists it's not about proving Einstein wrong; it's finding something that can't quite be explained by general relativity, some deviation from expectations that would provide a spark for physicists thinking about new theories.

The situation is similar in particle physics. The Large Hadron Collider uncovered the Higgs boson. Awesome – that validated the standard model that physicists use to describe particles and forces. But we also know the standard model doesn't describe everything we see in the universe (dark matter, for example). So it would be really exciting to discover a totally new particle that we could use to come up with a new-and-improved standard model. -AG

As you're both science writers, what are your thoughts on the trend of sensationalizing science stories as reported by popular media? Do you think it's a good way to attract more interest in science from the general public, or does it do more harm than good by setting unrealistic expectations?

wadss

Not directly related to relativity, but it's an important question. My take has always been: there's so much amazing science being done, there's really no need to sensationalize. Obviously not everyone in the popular media agrees with me...

I think – and any science journalist worth their salt will tell you – that sensationalizing science stories to "attract attention" is a terrible idea. I suppose you might get a few more eyeballs if you stuff the phrase "alien megastructures" into your headline, with the requisite number of exclamation marks. But in the long run, it just kills the credibility of both journalists and scientists. The public becomes less likely to trust what they read (and by extension, the scientists as well); scientists become more wary of working with journalists for fear of misrepresentation. In the worst case, it can lead to bad policy decisions (see exhibit A: climate change). And I think you're right about unrealistic expectations.

The journalist's job comes down to this: inform. If we sensationalize, we fail at the most basic tenant of our profession. -CC

I expect this to be a very loaded answer but without Einstein ever discovering his theories how might the world be different today? What wouldn't exist?

DrAquafresh793

Well we wouldn't know why Mercury's orbit is messed up. Can you imagine living in such a dystopian world?

I already mentioned GPS in my answer to /u/cbg79, which only works if you know about general relativity. $E=mc^2$ leads to things like nuclear energy (also nuclear bombs, so that might be toss up...).

We'd also have far fewer quotes on the internet misattributed to Einstein. But as Einstein himself said, "the trouble with quotes on the internet is you can never tell if they're genuine." -CC

I expect this to be a very loaded answer but without Einstein ever discovering his theories how might the world be different today? What wouldn't exist?

DrAquafresh793

GPS wouldn't work so well, for starters. But our whole outlook of the universe would be different. Modern cosmology owes its existence to general relativity. -AG

What are some tangible things that most people use day to day that exist only as a direct result of relativity?

cbg79

GPS. Without relativity, we'd be stuck using maps and asking for directions. <shudder>

The Global Positioning System, which among other things lets your phone yell at you when you miss a turn while driving, depends on a system of satellites and exquisitely accurate clocks. Those satellites are a) high above the Earth and b) moving pretty fast, both of which impact timekeeping. According to relativity, two clocks experiencing different gravitational forces tick at different rates, as do clocks moving at different speeds relative to one another. If you don't account for the relativistic effects felt by the satellites, GPS simply doesn't work. Clocks onboard the satellites run faster than clocks on the ground by about 38 microseconds per day. That doesn't sound like much, but it leads to position errors building up to around 10 kilometers (6 miles) by the end of that day.

At that point, turning down the wrong street would be the least of your problems. You would have turned into the wrong town instead. -CC

A little off subject, but related to space time (Hollywood style)

My son, who is 15, and I were having a casual conversation about super powers and which one would be best to have and use. He has been recently contemplating a time stopping watch. In jest, and in true Hollywood style, I explained for ever super power there must be a villain. Stereotypically, the ICBM's are left hanging just above crowded cities as the stop watched is used and then must be left on or the destruction of mankind ensues.

With a burst of insight, my son then questions Hollywood's version of physics. "Would gravity still work if time stopped?". He was asking w
Thanks for reading my crazy question.

grimpind1

Hmm...well, from my own experience with stopping time (aka stuck in an airport terminal overnight), I think gravity would still work. According to GR, gravity is a consequence of anything with mass contorting the fabric of spacetime (the classic bowling ball on a rubber sheet analogy). The contortions are just the shape of spacetime, regardless of what time is doing.

Now falling, however, requires time to move forward (because it involves something changing). So the

ICBMs should stay right where you left them, giving you plenty of time to relocate them somewhere safer.

Frankly I don't know why any country hasn't explored this as a nuclear deterrent yet... -CC

I would have to assume that using the theory of general relativity is how we discovered gravitational lenses.

My question is how without his theory how would you explain the effect, or would we think galaxies are closer than they appear.

DoYouReallyCare

(Sorry I posted this in wrong place earlier...) I wish I could remember where I heard this, but I remember someone writing “You can’t bend it like Newton, but you can bend it like Einstein.”

Gravitational lensing was first seen in 1919 by Arthur Eddington during a solar eclipse. He was looking for evidence to support Einstein’s theory, which predicted that gravity could deflect light. Now Newton’s theories also predict that gravity can bend light, though that only works if you assume photons have mass. In that case, photons fall just like apples and moons. The big observational difference is that Einstein’s theory predicts two times as much deflection of light as Newton’s. Eddington was looking at how the apparent positions of stars flanking the sun were tweaked by the sun’s mass. The observations were closer to Einstein’s prediction, which was a big victory for Al. So in that case, GR sent astronomers looking for a gravitational lens created by the sun.

The first deep-space gravitational lens was stumbled upon in 1979. Astronomers Dennis Walsh, Robert Carswell, and Ray Weyman were doing some follow-up observations of quasars (very energetic cores of galaxies that host actively feeding supermassive black holes) when they noticed that one of them was a double. Further observations revealed that the “two” quasars were at the same distance from Earth and were chemically identical, which suggested to the team that they were seeing two images of the same object. They realized that the most likely explanation was that they had found the first evidence of a gravitational lens. The double image seemed to be caused by a galaxy that sits between Earth and the quasar; its gravity laid out two paths for the quasar light to traverse on its way to Earth.

You can still explain the effect without Einstein (thanks Newton!), though I’d imagine you’d quickly start running into complications. There’s that whole photons-don’t-have-mass thing. You might get the distances wrong at first, but I’d think that you’d start running into contradictions in cases where you can directly measure the distances of both the lensed object and the object creating the lens (as well as estimate the mass of the intervening galaxy). I think that someone would have stumbled onto Einstein's theories eventually... -CC

What is your take on what will happen when the universe reaches it's ultimate expansion and goes cold? What will happen to the wave form light particles during the events?

Also, what effects will Dark Matter and the singularities in the Supermassive Black Holes have on this process?

Thanks in advance for your time!

Ego_Sum_Morio

Here’s what we know: There’s some weird entity called dark energy that dominates the universe and makes it expand faster and faster. We’re not sure whether the influence of dark energy will change in the future. Most likely the universe will continue its accelerating expansion, stars will run out of fuel, and our universe will be cold and dark and empty. But depending on dark energy’s influence, it’s also possible that the universe will contract (Big Crunch) or tear itself apart (Big Rip). For those planning for the (long, long, long-term) future, I wrote a survival guide a few years ago: http://discovermagazine.com/2011/dec/16-how-to-survive-the-end-of-the-universe. -AG

What are some reasonable alternatives for what's going on inside of a blackhole, other than the singularity? Would it be possible say for a super dense ball of magnetic monopoles to be at the center?

Magnetic monopoles are predicted by Grand Unified Theory (and M-Theory) but we don't hear much about them (as they would have mainly existed a few Planks after the Big Bang, around the time of inflation). Could they be at the heart of black holes?

theothercoolfish

Well right now physicists are jostling with the possibility that there is no inside of a black hole. A 2012 paper argued that there could be an impenetrable wall of energy at the boundary of a black hole -- a firewall. This paper actually sparked the recent work into linking quantum entanglement and spacetime. -AG

Years ago (ok decades) I was under the impression that while Max Plank promoted Einstein, Hendrik Lorentz was disappointed that his Transformation formulas and theories were not accepted as the be all explanation that was the encompassed by Einstein's Theory of Relativity. This disappointed was (in some way out of respect for Lorentz) a primary reason that Einstein was never awarded a Nobel for ToR and would not receive a Nobel until after Lorentz had died. However I can find nothing that supports this today. Is there any truth to this? How was the ToR received and why did Einstein not receive a Nobel prize for it (are there other reason?)?

Mojeaux18

Science News managing editor and history of physics guru Tom Siegfried informs me that Lorentz and Einstein were always on good terms. Lorentz actually nominated Einstein for a Nobel in 1920. "The Nobel committee awarded the prize to Einstein for his paper explaining the photoelectric effect rather than for relativity because relativity was still a controversial topic in those days, hard for many scientists to evaluate, yet everybody believed Einstein should get a Nobel. At least that is the most common explanation." -AG

What is the best way to explain Einstein's theory of relativity to a child?

Insomniaking

That's a tough one. I'll let Chris come up with something :) Somewhat related, you should read Randall Munroe's description of GR using the most common 1,000 words: http://www.newyorker.com/tech/elements/the-space-doctors-big-idea-einstein-general-relativity. -AG

What is the best way to explain Einstein's theory of relativity to a child?

Insomniaking

Wait until he/she is older? :-)

Our managing editor took a stab at this in an article for Science News for Students: https://student.societyforscience.org/article/einstein-taught-us-it%E2%80%99s-all-%E2%80%98relative%E2%80%99 -CC

Recently, loop-free quantum entanglement experiments featured prominently in the news (and also in this sub-Reddit). These experiments involved entangled quantum particles a mile apart. If spacetime is stitched together by entanglement, would this imply that mile-long Einstein-Rosen bridges get formed in these experiments?

Kapede

It would be pretty sweet, wouldn't it? That's not necessarily the case. ER = EPR (Einstein-Rosen bridges, or wormholes = Einstein/Podolsky/Rosen, entanglement) is a cool idea because mathematically entanglement and wormholes seem like two sides of the same coin. But it will take a lot more research to make the case that there are actual physical wormholes that link entangled particles. -AG

I would have to assume that using the theory of relativity still hold weight in contemporary scientific circles?

skaterboi_94

Yup, it's aging pretty darn well. Plenty of people have already pointed out my flaws, and I'm not nearly 100. -AG

The Advanced LIGO detector is designed to detect the theoretical gravity waves that GR predicts and was expected to be operational near the end of 2015. When should we be expecting published results? And what would it mean for GR if A-LIGO doesn't detect gravity waves?

theothercoolfish

(Answered the wrong question here earlier...) As of September, AdLIGO is operational! It's a bit tricky to say when we'll see results since they're, by definition, unknown. The LIGO researchers I've spoken to are hoping to see something by 2017. Though even if they detect something tomorrow, it would be a while before anyone saw a published paper. Lots and lots of verification and follow-up would be needed — the researchers want to make absolutely sure they're publishing a real detection.

As far as what a nondetection would mean for GR: very little probably. We've already detected gravitational waves indirectly. In the 70s, astronomers observed a binary pulsar spiraling toward its companion at the rate predicted if the duo is radiating gravitational waves. There are also, of course, the many, many observations of gravitational lenses and the many successes of modern cosmology, all of which depend on GR. A nondetection would say less about GR and more about the population of objects in the universe that blast out gravitational waves. Perhaps, for example, supermassive black holes don't collide as often as we think (there's already some evidence that this is the case).

A space-based detector, such as eLISA, which has been proposed to the European Space Agency, will be really helpful here. It will detect gravitational waves from certain types of binary stars in the Milky Way that we already know exist. That will be useful for calibration, which in turn should help out the search for things that we haven't seen yet. -CC

Hello! If the sun magically disappeared instantly, how long would it take for its gravity to not affect the Earth?

owencrump

/u/theothercoolfish beat me to it. Yes, it would take more than eight minutes for our orbit to be severely messed up, let alone all the other issues that would come from losing the sun. The disturbance would come in the form of gravitational waves, which Einstein predicted and the Advanced LIGO experiment is looking for right now! -AG

What can you describe about time? Is our perception of time just an illusion? Does it have a direction? Is it infinite?

the_gr33n_bastard

Well let's start with what Einstein showed: The universe has no master clock; time is relative. My watch ticks at a different rate than one worn by an astronaut on the International Space Station.

Why time flows forward is actually a really cool and perplexing area of research. The laws of physics seemingly would work just as well if time moved backward – there's no preferred direction. Most physicists believe time's direction is tied to the second law of thermodynamics, which says that if left alone systems tend to become messier/more disordered. That's led to some pretty cool ideas about our universe's arrow of time: https://www.sciencenews.org/article/arrow-time. -AG

Does the warp drive **theoretically** allow faster than light travel without violating any laws of relativity?

And What is your take on feasibility of humans reaching other stars in a couple of centuries from now?

silwill

My personal warp drive invention not only doesn't violate laws of relativity, but also preserves all rules of etiquette. Beat that Zefram Cochrane.

We're having trouble getting to Mars in any reasonable amount of time (isn't it always 30 years away?), that barring an actual warp drive engine, I just don't see it happening. Not in a couple of centuries anyway.

Also, it's hard to wrap our brains around just how far apart everything is out there. The nearest star to the sun is Proxima Centauri, about 4.2 light-years away. The space shuttle would need about 165,000 years to get there. And that's not counting bathroom breaks...-CC

What is your favorite color?

SilentMajority420

Cerulean -CC

GR says gravity is the acceleration caused by the bending of spacetime. Why would a particle (say graviton and/or dilaton) need to be involved? (Or is that a natural extension of the prediction of gravity waves?)

theothercoolfish

In short, because other forces have elementary particles that "transmit" the force - like the photon for electromagnetism. But you've hit on the major problem facing GR: why it breaks down at the quantum level. If physicists can describe gravity at large scales, they should also be able to describe it the quantum level with a particle like the graviton. -AG

How is radiation able to escape a black hole?

It-gets-bigger

Nothing that passes the event horizon (the boundary of a black hole) can escape. But a black hole can still radiate because of what happens right near the horizon. Stephen Hawking predicted this in the 1970s, and it's a major issue because if black holes eventually disappear, then what happens to the stuff inside? Answering that question could help bridge the gap between general relativity and quantum mechanics. Here's a good description of Hawking radiation from a 2004 SN article (https://www.sciencenews.org/article/information-please):

"According to quantum theory, the vacuum of space isn't empty but seethes with pairs of elementary particles winking in and out of existence. One partner in each pair has negative energy, which keeps that particle gravitationally bound to the black hole, while the other has positive energy, which gives it enough oomph to escape from a black hole.

If such pairs come into existence just outside the event horizon, sometimes the negative-energy particle will fall into the hole, while the particle with positive energy will remain outside and eventually escape.

From the point of view of a distant observer, the black hole's event horizon radiates positive-energy particles, a phenomenon known as Hawking radiation. However, these particles seem to carry no information about the contents of the black hole.

Now, consider the negative-energy particles that the black hole has absorbed. According to general relativity theory, mass and energy are equivalent. Therefore, a black hole that absorbs a negative-energy particle loses mass. If there are no nearby planets or other detritus to nourish it, a black hole absorbing negative-energy particles will eventually vanish." -AG

Thank you for doing this AMA! I am an astrophysics student and reading about astronomy and physics in Science News is one of my favorite pastimes. I am currently planning on going to graduate school for astronomy, but I am also considering science writing. How exactly did you get into science writing? What made you decide to write about science instead of do it yourself? What were some challenges you faced?

planetary-motion

Well what you're planning is exactly what I did! I did research for a while (searched for exoplanets, got really good at not finding them), and then changed course to write instead.

For me, I realized I loved the end product of research but found the day-to-day reality to be very tedious. I got excited talking to people about what we're discovering out there. With that in mind, it was sort of a no-brainer for me to leave research.

I started dabbling in blogging during and just after grad school. But my "big break" came when I applied for a science writing fellowship through the AAAS (the Mass Media Fellowship), which places scientists in newsrooms for a summer. After 10 weeks writing for Scientific American, I was hooked. And here I am!

The biggest challenge for me was the vastly different pace of academia vs journalism. Working to very quick deadlines, one after the other, I found to be relentless and exhausting after years of doing work at something closer to a snail's pace. Also learning to separate what I might find interesting (some obscure result) from what a more general audience might find interesting took a lot of calibration. I'm still learning every day... -CC

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planetary-motion

I majored in physics, but the idea of becoming a physicist terrified me. I've always loved reading newspapers and magazines, so I jumped at the chance to combine my passions of science and journalism.

One thing I love about my job is that my short attention span serves me well. I can spend a couple of days talking to fascinating researchers studying black holes, write the story, and then go on to report a story about quantum teleportation.

And thanks for reading Science News! -AG