Science AMA Series: I'm Janna Levin—astrophysicist, author, and host of NOVA's "Black Hole Apocalypse." Ask me anything about black holes, the universe, life, whatever!

Janna$_{L}evin$[1]$andr/ScienceAMAs$[1]

[1]Affiliation not available

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Abstract

Thank you everyone who sent in questions! That was a fun hour. Must run, but I'll come back later and address those that I couldn't get to in 60 minutes. Means a lot to me to see all of this excitement for science. And if you missed the AMA in real time, feel welcome to pose more questions on twitter @jannalevin. Thanks again. Black holes are not a thing, they're a place—a place where spacetime rains in like a waterfall dragging everything irreversibly into the shadow of the event horizon, the point of no return. I'm Janna Levin, an astrophysicist at Barnard College of Columbia University. I study black holes, the cosmology of extra dimensions, and gravitational waves. I also serve as the director of sciences at Pioneer Works in Red Hook, Brooklyn, a non-profit foundation that fosters multidisciplinary creativity in the arts and sciences. I've written several books, and the latest is titled, "Black Hole Blues and Other Songs from Outer Space." It's the inside story on the discovery of the century: the sound of spacetime ringing from the collision of two black holes over a billion years ago. I'm also the host of NOVA's new film, "Black Hole Apocalypse," which you can watch streaming online now here. In it, we explore black holes past, present, and future. Expect space ships, space suits, and spacetime. With our imaginary technology, we travel to black holes as small as cities and as huge as solar systems. I'll be here at 12 ET to answer your questions about black holes! And if you want to learn about me, check out this article in Wired or this video profile that NOVA produced. —Janna

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JANNA_LEVIN R/SCIENCE

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Hello Janna, thanks for doing this.

I remember reading years ago about a possible black hole scenario:

A rotating black hole would increase its rotational speed as the mass collapsed further in on itself because of conservation of angular momentum, therefore some of the exterior mass would reach "escape velocity?" and would form a ring around the collapsing black hole. If I remember correctly, the overall mass of the black hole would cause a gravitational field that is survivable (no spaghettification) and could be used to either see the other side of the black hole or propel a spaceship to relativistic speeds.

Am I remembering complete gibberish, or is this a plausible cosmic scenario for black holes?

Thanks again!!

EDIT: I believe she replied elsewhere, I'll paste her response here:

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Lots of interesting ideas here. A rotating black does twist spacetime like a tornado so that material gets caught in the whirlwind, like cows and trucks and dirt all get swirled around with tornados. Even if you have no angular momentum you will get dragged around the hole and likely fall in. If you have some angular momentum of your own, then yes you could be cast into a swirling disk around the black hole. And many black holes do have bright accretion disks where the matter slowly dribbles in. Think Interstellar. That black hole was very accurately represented with a swirling disk. Separate idea: the bigger the black hole, the more easily you will survive transit through the event horizon and you won't be speghettified until you're crushed to death inside the black hole. It's harder to stand on a basketball (a small sphere) than the Earth (a huge sphere). Perhaps counter intuitively, you notice the curvature less and less the smaller you are compared to the size of the event horizon. All black holes, rotating or not, allow you to see behind them because even light travels along the curved spacetime. If you were to shine a flashlight directly "behind" (can't say which is the front or the back) a black hole, some of the light will fall in, some will spray out and its path will curve around the black hole so that those standing on the other side will see your flashlight. The lesson: Don't hide behind a black hole. They can still see you.

EDIT 2: To expand on the question as u/WholeLot pointed out, I was apparently referring to a ring singularity or Kerr ring. Anything you'd like to add here Janna regarding this ring singularity or Kerr ring?

Thanks!!

patanwilson

Welcome Everyone! We're on!

Is it possible our understanding of black holes is flawed? What are some possible ways we might be misinterpreting the reality of the situation?

j4p4n

It is always possible that our understanding is flawed. I would say it is extremely likely that our understanding of big black holes is very very very good. Where we run into our limitations is when black holes are small, microscopic. Then we are pushing the boundaries of quantum gravity where we are still grappling with fundamental ideas. The black hole provides us clues, a playground on which to work out these deep concepts.

NDT brought up an interesting point on The Late Show recently about how the universe will/is expanding beyond the horizon. Do you think we've actually already lost cosmic information previously available to us or is this like a billions and billions of years from now kind of thing?

PHealthy

Yes, as a cosmologist friend of mine says, that's why we have to do astronomy now. If the universe continues to expand eventually all the other galaxies in the universe will be so far away and dragged away from us so rapidly that the light emanating from them will never get to us. It's a cosmological event horizon. With many similar features to a black hole event horizon. If the expansion is strong enough, our galaxy will be ripped apart and all the stars will drift across the horizon as well and the skies will go dark. This is already happening so that there are galaxies that have moved beyond our observable universe.

With the size of Sagittarius A what kind of star or other event is capable of creating such a large black hole? Or did it simply absorb enough mass to obtain its size? And how long would it take something of its size to fizzle out due to Hawking radiation?

Monolith1011

Luckily for our prospects for employment as scientists, there are many great questions to left to ask. And this is one of them. That's the real fun. To ask questions we don't yet know the answer to and to struggle and sweat to try to answer them.

We don't yet know how black holes got so big. Very likely some black holes formed in the earlier universe without becoming stars first. There may have been enough mass swept together to directly collapse to big black holes which then merged and grew bigger and took down all the debris and stars and dust and gas available to them in the densest regions that became the galactic center to get bigger still.

It could take somewhere near 10^{100} years for supermassive black holes to Hawking evaporate. For comparison, the universe is only 10^{11} years old, which is 10 billion years (more accurately the universe is not quite 14 billion years old). The future is much longer than the past.

Thanks for taking the time for this AMA!

After watching Nova the other night, the early development of black holes in the young universe seems to have been critical for the establishment of galaxies. This early universe was a smaller place due to the expansion of the universe, could super-massive black hole has been formed by black hole combining in a smaller volume of universe? If so, what would the effects of the gravitational waves generated be on the structure of galaxies? It's a simple, and inaccurate analogy, but if you watch the surface of a pond, small floating bits of leaves and what not tend to be driven together by the motion of the surface. Would these gravitational waves actually empart force on matter?

nate

All good questions. Yes black hole formation in the early universe may well have skipped the whole star formation followed by death throes. Gravitational waves are agonizingly weak, as is gravity in general. They can't bounce around big masses, which is why LIGO needed to suspend the mirrors so delicately so they could bob on the wave. The mirrors in LIGO move by a ten-thousandth the width of a proton.

What advances in science do you see being made within the next ten years?

RYMN8R

I'm better at predicting phenomena on the scale of many billions of years. Apologies. We all have our ranges.

It has been said that the directions of space and time "reverse" within the event horizon of a black hole - the singularity effectively becomes your unavoidable "future". Does this mean that there is some degree of freedom to move through time or receive information from the future in the moments before you reach the singularity? I'm assuming a really huge black hole where tidal forces may be survivable near the event horizon?

Pynchon_A_Loaff

Yes, I love this. Think of a black hole as inducing a rotation of space into time and time into space for an infalling astronaut relative to a space traveller at a safe distance. At the event horizon the rotation is complete. All of the infalling astronaut's time has been rotated away and they appear to freeze at the horizon, time effectively stopped. However, from the astronaut's point of view, time ticks completely normally and she falls across the horizon in short order. Inside the black hole, the rotation overshoots. What the distant space traveller called a spatial direction has become a time direction and the infaller sees the singularity not in the center of a sphere, but in her future as inevitable as the next second is for us. There is no more freedom afforded. The singularity can no more be avoided than the conclusion of this hour.

Saw Nova on Wednesday. Entire family enjoyed it.

Is it possible that our entire galaxy or even the observable universe is inside the event horizon of a gigantic super massive black hole? How can we detect that this is or is not the case?

For such a large black hole, is it possible that objects can escape out of its event horizon through cosmic expansion of space?

invalid_dictorian

Excellent. Great to hear. We can map our cosmic spacetime pretty well and what we observe is an expanding universe full of other galaxies. There are as many galaxies in the observable universe as there are stars in our own Milky Way. That is a very different spacetime description from the interior of a black hole, which drives all matter to crush together in a future singularity. However, we do see a cosmological event horizon, a region beyond which no light can get to us. So galaxies that are too far away from us can beam light our way in vain. That light will never reach us.

I was confused by some data related to LIGO's observations of gravitational waves. Say you have two black holes, each weighing 20 Solar masses. They merge together, the resulting black holes weighs say 30 Solar masses, while 10 were radiated away as energy of gravitational waves. Now, if nothing can leave black holes, how was that huge amount energy able to leave them anyway?

DigiMagic

This is indeed very subtle. Black holes are nothing. They could be formed as part of the initial conditions of a spacetime. So when we say they have "mass" we mean they have some gravitational energy associated with them that is a mass equivalent. When too black holes merge the new black hole must be bigger than each, but amazingly doesn't have to be bigger -- or even as big -- as the sum of the two. And in fact the merger releases some of their gravitational energy without releasing any matter. It's a good question.

This may be a silly, simplistic question with a difficult answer... But what is the current theory for what's in / on the other side of a black hole?

imzombie

This questions intrigues everyone, including professional scientists. Fact: We don't know. But that's half the fun. It may be that there is the birth of another universe. It also may be that in some subtle way there is no interior to the black hole. The interior is an illusion and instead there are wormholes that map the outside to the inside. Stay tuned for the next 50 or so years as we work it out.

I watched your Nova episode, and it was fantastic! Your hosting was excellent.

In the special, it is mentioned that there is a limit to how much material a supermassive black hole can consume in a period of time, due to the photonic pressure of the light emitted by the accretion disk. Does this mean that quasars would actually be *more* bright if this limit did not exist? Also, would this not suggest that many quasars would be of equal brightness, since they have reached this limit?

My second question is this: It is mentioned that inside the event horizon, an observer (the astronaut who got e't by the black hole) would see the entire future of the universe play out due to time dilation. However, give the funky things that black holes do to the path of light in the vicinity of the event horizon, would the geometry of space-time allow the light entering the black hole to even be coherent enough to extract such an image, let alone see it with one's eyes? I know there is a lot of talk about information being consumed by black holes, but is that information in any kind of coherent form once it is inside the black hole?

daneelthesane

Thank you! That means a lot to me. Much appreciated.

Quasars may derive their brightness by twisting up magnetic fields. They form batteries in an electromagnetic engine. To crank up their brightness, I suspect you would have to crank up the magnetic field pinned around the black hole in that accretion disk.

In this limiting format I can say this, the light would be focused at you so that what we really expect is a bright flash of white light. Not to quote myself, but it would be like the bright light at the end of the tunnel in the purported near death experience. Only it's a total death experience.

Can we create mini black holes and use them for technology? Are there certain attributes limiting the mini black holes we create from being usable?

Gregbot4

In theory, we should be able to create mini black holes, much the same way we create other subatomic particles, by smashing things together. It's always fun to smash things together. Black holes are like fundamental subatomic particles, like an electron or the Higgs. But they require much much higher energies for their creation than we anticipate reaching in our accelerator experiments.

The problem with mini black holes is that they evaporate through Hawking radiation nearly instantaneously. The smaller the black hole, the more explosive the evaporation. There may be a way to stabilize them by fattening them up, but that would be dangerous since they'd be able to eat your laboratory.

In your opinion, When do you think technology will be advanced enough for humans to capture images or footage of an actual black hole?

Iwillreign

Soon! The event horizon telescope already has data collected by organizing telescopes around the globe to act as one giant eye. They are staring at our our Milky Way's own supermassive black hole in the direction of Sagittarius. That black hole is 4 million times the mass of the sun, but only a few sun widths wide and is 26 thousand light years away. That will be like resolving a piece of fruit on the moon. But they will do it.

Have you seen the movie "interstellar?" How realistic is the halo of light around the black hole in the movie? Also, if "white holes" do exist, what is their relation to black hole and how would they affect spacetime, compared to a black hole?

ObeliskOfficial

Yes. I am a big fan of Kip Thorne's, the brilliant astrophysicist who wrote the original treatment for Interstellar and who won the Nobel prize alongside Rai Weiss and Barry Barish for LIGO's success. Not a bad run. The black hole is very realistic. The animators actually used the general relativistic equations to simulate the event horizon. Essentially you see a bright accretion disk around the hole and you also see it above and below because the curved spacetime sends you light from the other side of the accretion disk on bent paths that reach you from around the north and south poles.

About white holes, all I can say is that they are beautiful conjectures. Possibilities not predictions. They are the opposite of a black hole in some sense. Stuff can only come out, never go back in.

If Black Holes are “rips” in space time, at the Planck length, what is on the other side of space time?

surffawkes

If only we knew. Here the predictions of general relativity become unreliable. Like a dying man scrawling in the dirt, relativity is telling us something as it breaks down. The singularity is a clue not a genuine prediction, a clue that some other law of physics takes over at these Planck scales. That theory will predict for us what is on the other side. For now, we can conjecture. Maybe a big bang? The birth of a new universe?

Hey there, thanks for the AMA!

What is the best way for someone who just has a basic understanding of physics to get into astrophysics and understand the universe a bit more ? Can you recommend any series, youtube series or book series that explain things in a simple yet interesting and detailed way ? Could you recommend something for my 11 year old sister as well?

rizombie

There are many popular science books that range in style and level. I personally love very narrative books and think they provide a very human illumination of the passion of science. I'm not going to plug my own books (ha, ha just sorta did: Black Hole Blues). Kip Thorne's book, Black Holes and Time Warps is a great example of a pedagogical style. Take your sister to look through a telescope. It's transformative.

Black Hole Apocalypse discussed a black hole that is 6,000 light years away. In our search for other black holes, do we have enough data to know that there are not any within close enough proximity to affect our sun and Earth in the next thousand or million years? My 11 year old son wants to know after watching your show.

R0boto

Sweet. I hope we have not provoked anxiety. If there were a black hole so close that it could cause our solar system harm, we would actually be able to detect it through gravitational lensing. The black hole

could be seen causing a twinkling of the light from other stars as it moved across the sky. We're safe. At least from that. There may be other black holes closer than 6000 light years, but not so close that I'll lose any sleep over them.

Seems like an odd question, but what inspired you to become an astrophysicist?

SketPanda

Not odd at all. I was in college studying philosophy because I loved the big questions. I felt astrophysics had better answers. And, unlike with Kant, no one was laboring over what Einstein meant. Once he laid out relativity it was a gift. Once the tool was acquired, anyone could own it and use it. Transcended everything.

Where do you think the matter pulled in to a black hole goes? Surely all the matter from millions of years can't just keep infinitely compressing? What do you think their inner..structure? Might be like?
Will Matthew
McConaughey be ok?

For some reason, magnetars are extremely interesting to me, they're a fascinating level of fuckery. LIGO spotted two neutron stars smashing together recently, what would be the difference? Would the the fuckery be off the charts? Thanks!

Bigbananajoe

Agreed, agreed. That's in no small part why the interior of black holes continues to attract the attention of theoretical physicists. There are many suggestions out there including vibrating quantum remnants. But they all have noteworthy problems. The latest ideas involve the suggestion that the black hole is a hologram with no actual interior. According to this idea, all the quantum information is smeared around the event horizon in the form of oscillation strings. There is much mathematical evidence that there can be no more information packed into the interior than can be smeared on the exterior surface of the event horizon. That smells like a hologram.

What's the next step for data collection? Are you able tell us anything about the improvements being done to Advanced LIGO if there are any?

WesatWork

LIGO is currently offline as upgrades are made. The team is analyzing noise that continues to haunt the high frequencies and fascinating advances are being made on the quantum aspects of the detector, involving squeezed quantum states of light. However, LIGO might not do more than a few times better than it is now. For that, we might need to go to space.

As space time curvature increases, time slows. At a black hole, time slows to 0. Is this at the singularity or the event horizon? Does time stopping mean velocity stops, so the fall into the singularity takes infinite time from an external point of view?

TaviRider

The infinite time dilation you are describing happens at the event horizon. The time dilation is relative to the time of an observer far from the black hole. From the perspective of the space traveler crossing

the event horizon, her own time is completely normal. Her clocks tick normally. She ages normally. It's the rest of the universe that's sped up.

What's your favorite star?

melodyofmymind

Ooooh. I'll have to think about this. But you gotta love Alpha Centauri for being so close.

What are your thoughts on death and consciousness?

gulpy

We had an event on Consciousness recently at Pioneer Works in Brooklyn, where I'm also director of sciences. My guests were Christoph Koch and David Chalmers. We were in conversation about the unsolved problems. Fascinating, truly. I suspect consciousness is an evolutionarily adapted tool to manage too much information than our processors could manage and still navigate the world. We have to simplify and declare coarse level comprehension quickly. Like identify "baby" nearly instantly. A computer can't do that. But a computer can process the glut of input data staggeringly more effectively than we can. So AI might not need consciousness. We had the conversation in a series at Pioneer Works called Scientific Controversies. We'll put the recordings out in the next few moths. www.pioneerworks.org

Are we living in a black hole that formed in another universe?

DeadPrateRoberts

Even if a black holes interior leads to a big bang -- or even a series of big bangs for every little bit that falls in -- that new universe doesn't live inside the event horizon quite in the way I suspect you're visualizing. Imagine a long trumpet horn. The narrow part near the mouth piece is far from the big wide open horn and doesn't feel inside it. I admit, the analogy is imperfect. Plus the big bang will be in the past. Remember it's spacetime. Not just space.

If a grad student wanted to study black holes further, which avenues would be the best approach? ie theory, LIGO type experiments, GR?

matthewshead

So sorry, have hit the end of the hour. I'd love to come back later and make it through the remaining questions. But I would say this. It has to be all of the above. I'm not an experimentalist. But you must take all the classes, study GR, cosmology, astrophysics, particle physics, and at keep an eye on the experiments if you are a theorists. Best of luck.