Black Holes

Midnight Facts for Insomniacs

Podcast Transcript

(Note: transcript consists of episode outline)

These last couple of episodes were very hi-tech and science-heavy and so I'm looking forward to a fun light-hearted non-technical topic. So maybe we'll get one next week. They did it to us again, the insomniacs are sadists and they enjoy listening to me bumble through Byzantine scientific jargon and mangle 12-syllable words.

This episode is about black holes, and my entire goal for the next 45 to 60 minutes is to not make a single anus reference. I feel like we will fail, but we must try. This is a serious episode about a serious topic and we must treat it with the weight and gravity that it deserves. Do you get it? This is already a fail.

No, this is actually going to be a really interesting episode, I love this topic so much, this might be my favorite subject I have ever researched on this show. Just because it led me down so many different wormholes, so to speak. I watched endless YouTube videos, I fully geeked out for about a week. This is my jam. Science stuff but also mysterious and a little bit scary and kind of existentially triggering. New kink unlocked.

At its most basic, a black hole is a point of infinite gravity. Gravity increases with the addition of mass and most importantly with density; for our purposes today a black hole is created when a celestial object has been compressed so intensely and developed such a powerful gravitational field that not even light can escape. Now that's the standard, clichéd, boring explanation. You could also say that a black hole is a fascinating scientific conundrum that no one fully understands. Even scientists will fully admit that black holes represent a paradox that has yet to be resolved. Maybe we'll solve it today. What better candidates for resolving the mysteries of the universe than two middle-aged underachievers with Bachelors of Arts degrees on a podcast. Maybe not. But I think the easiest way to understand a black hole is to virtually experience one, so we're going to start by taking a journey into the black hole at the center of our own Milky Way galaxy. Did I mention that there is a black hole at the center of galaxy? And not just the Milky Way—most galaxies, in fact, maybe all of them. Midnight Fact number one. Do you know what our black hole is called? Black holes are named with an asterisk because an asterisk looks like a star; scientists…seven years old. in fact when you see the asterisk you say the word "star" in order to invoke the relationship between stars and black holes, So the name of the supermassive black hole at the center of our galaxy is Sagittarius A, and then an asterisk, and you say it Sagittarius A-Star. I hate that name. It just feels so condescendingly on the nose. Sagittarius. a star. We get it. Most black holes used to be stars. (Other than theorized primordial black holes, which may have been formed during the Big Bang.) There are many aspects of black holes that are theorized at this point without being confirmed. So it's a little bit of a challenging topic to cover with authority. And also because there are only a few people on earth who even claim to understand the full implications of the science that we're dealing with. And many of them are probably faking it. That's my theory, it seems so easy to get away with because who's going to call you out? The other two people? They're probably faking it too. No, there is definitely a small group of people who understand relativity and you and me are not part of that group. so I'm in the weird position of having to try to explain something that I myself don't understand...but let's be honest, this is not an uncommon situation on this show. Thinly and unconvincingly concealing ignorance is my comfort zone.

A little backstory before we begin our journey to sagittarius a star; btw Duncan you should be packing right now, it's going to take a while. Like, eons. Anyway, The idea of a black hole was actually proposed way back in 1757 by English clergyman and astronomist John Michell. I did not know this, I thought black holes were first revealed by Einstein's equations, common misconception. Michell referred to them as "Dark stars," which is pretty badass, and less buttholish, I prefer it, but Michell's concept of a black hole was wildly off-base. Not his fault, the guy was working with the tools he had, basically peering through a papertowel tube pressed against a monocle. But it wouldn't be until Einstein unveiled his theory of general relativity that the concept of black holes entered the collective consciousness. Einstein's equations explain the relationship between gravity and time and matter, and strongly implied that black holes had to exist, but there was no physical, direct, incontrovertible evidence until decades later. Black holes also still weren't called black holes, initially scientist referred to them as "Gravitationally completely collapsed objects." Less scatological than black holes yet somehow worse. The term "black hole" didn't enter the zeitgeist until the 1970s, it was coined in 1968 by Princeton physicist John Wheeler. The first celestial object that was widely accepted to be a black hole was discovered by a rocket launched from White Sands Missile Range in New Mexico, in 1971, and is known as Cygnus X-1. The first *picture* of a black hole was taken by the event Horizon telescope, (the term event horizon will never not be scary to me because of that movie). The event Horizon telescope is in fact a collaboration of multiple telescopes strategically placed around the world and their images are composited to create the final version. The image, revealed on April 10 of 2019, depicts the supermassive black hole at the center of the galaxy M87, aka Messier 87. Only slightly smaller than the nearby galaxy hot messier 88. And when I say supermassive, I'm not kidding. That black hole is equivalent in mass to more than 6 billion suns, so it's large, but it's also really far away, more than 55 million lightyears away, so it was quite an achievement to get a picture of it. And it's especially impressive to get a picture of an object that can't actually be photographed and isn't even technically an object. The phrase "picture of a black hole" is a contradiction, you can't take a picture of something that is incapable of producing or reflecting light. By definition it's impossible to take a photo of a black hole, it would be like taking a picture of empty space between stars, there's no light to be seen. I'll show you the photo, and what you're seeing here—it looks like an inflamed sphincter—is not the black hole itself but rather the accretion disc and the the photon sphere. I say it often: we'll get to those. So the same terrifyingly-named telescope also gave us our first picture of Sagittarius a star, the destination of our trip. That photo was revealed three years after Messier 87, in May of 2022. Both photos look pretty much exactly the same, and of *course* they do, they're pretty much the same thing. Sagittarius a star is much smaller than M 87, but also much closer, so the resolution is similar. Now It had long been suspected that the center of our galaxy hosted a massive black hole. Or maybe it would be more accurate to say that it has long been suspected that a giant black hole at the center of our galaxy hosted the entire galaxy…the galaxy wouldn't exist without it. That is why galaxies stay together, the supermassive black hole is the gravitational mass around which everything revolves, the same way the earth revolves around the sun and the moon revolves around the earth. And incidentally, I use the word "revolve" for a reason; there is a difference between the words revolve and rotate. Rotate is to turn in spin around an axis, the way the Earth rotates to create night and day, while revolve is to orbit around another object the way the Earth revolves around the sun, or galaxies revolve around Sagittarius a star. (Don't forget, it used to be a star. This is how I should have been named. Shane, a star. I want an*. I probably do have an asterisk, but like the ones in baseball. A footnote: ignore everything this guy says. So the existence of Sagittarius a star was predicted by scientists, based on the movement of solar systems around the galaxy. However, scientists are a cautious bunch, and they should be (especially nuclear scientists and people designing airplanes or whatever). But when it comes to black holes, scientist were very nervous to pull the trigger. As recently as 2020, just four years ago, when two scientists were awarded the Nobel prize for their work on Sagittarius a star, the actual wording of the award says that it's the result of "the discovery of a supermassive compact object at the centre of our galaxy." Notably the words black and hole are absent. Maybe because the people on the Nobel committee had the same concerns that I do about the potential for butthole associations. You don't want your prestigious award associated with cosmic anus. (We gave up on that goal forever ago). I wonder what the Nobel committee would do if they had to award scientists a prize for discovering information about Uranus. Ok, so let's hop in our extremely advanced spacecraft which of course is capable of traveling close to the speed of light. And don't ask where I obtained this spacecraft. You don't wanna know, it's classified,. I'll just say it's a spacecraft that I have named the hubris, it is powered by sheer recklessness and delusion. I have those in abundance. And we need those qualities, just like we need the fastest possible spacecraft we can get our hands on, because Sagittarius a star is very dangerous and very far away. Traveling AT the speed of light, it would take us about 27,000 years to reach Sagittarius A-star. So…Bring Scrabble. And snacks. The problem with this episode, other than neither of us understanding it, is that like 98% of the objects and phenomena that we're going to be discussing exist on a scale that is simply not conceivable by humans. Even humans that are smarter than us, which is probably most humans. But these are mind-boggling concepts. Light travels 186,000 miles every second, 300,000 km/s, 671 million miles every hour. And if light were able to escape the black hole at the center of our galaxy it would take 27,000 years to get to your eyes, you would be witnessing events from almost 30,000 years in the past because sagittarius a star is 152 quadrillion miles from earth. I feel like I'm just making up words and numbers, and I might as well be, if you told me the closest black hole to earth was a gazillion megaparsecs away I would just nod agreeably and probably repeat it to someone else, that's how little I understand this stuff and how easily duped I am by anyone who sounds smarter than me. Which, again: a significant portion of the population.

So now we're in our spaceship and we have a lot of time to kill because we're headed to Sagittarius a star, so we're going to take this opportunity to learn a little bit about our destination and black holes in general. And as you've learned (because scientists are captains obviouses who have to attach the word star to everything starlike) there is *usually* a connection between stars and black holes. Most black holes were once glorious, shining stars, which are beautiful twinkling beacons in the night sky and also nuclear fusion reactors. A star is a fairly in hospitable environment, fundamentally it is a tight ball of contained, controlled explosions and the only reason stars don't burst out into space and instantly disperse is because of gravity. Gravity, as you know, is a function of mass; the more mass an object have, the more it bends space-time, and thus the more gravity they have. stars are so huge and dense that their gravity keeps the explosions contained and under control. And the fact that gravity has the power to contain a star is sort of counterintuitive, because gravity is actually an extremely weak force. It's literally classified in textbooks and online as the weakest of the four fundamental forces. Scientists like to diss gravity. "The most pathetic of forces." You could at least come up with another word besides "weak." The most modest of forces. Gravity is humble, it doesn't need to be parading around being all powerful like electromagnetism, or the nuclear forces. But even though gravity is capable of creating the most powerful phenomena on earth—black holes---if you think about it, the idea that gravity is fundamentally weak actually makes sense. The earth is huge, but tiny creatures like us can still resist its gravity, we can run and jump and lift luggage onto those abacus rollers in the security line at the airport. Every time you toss a tennis ball for your dog, you're overcoming the gravitational force of the entire planet. And the effect of gravity is very localized; if you get a few miles up in the air, it feels like earth's gravity completely falls away, you're suddenly floating around the cabin and feeling very queasy…you're still subject to earth's gravity, which is why a spaceship can end up in an orbit around the planet, but it takes a long time for the earth to pull you back down because again, gravity, a weak little bitch. just fucking pathetic. A giant loser.

So gravity is a loser, until mass and density increases to the point at which it becomes scary. When it comes to an object the size of a standard star, the mass and density of this giant object has enough gravity to hold the whole boiling, broiling, seething hydrogen reactor together…for a while. Eventually all of those explosions are going to expend the hydrogen fuel that a star needs to remain a star, and when the gravity becomes stronger than the force of those explosions, the star collapses on itself. This can happen in a few different ways based on the size of the star. The star at the center of *our* solar system, you might know it by its nickname: we have pet names for our star because we're a little bit biased—well, the sun will use up the rest of its hydrogen fuel in about 5.4 billion years. At which point its outer layer will expand and consume the three inner planets: mercury, Venus, and the earth. Meanwhile the sun's core will shrink and heat up, even hotter than before, which was already pretty damn hot. This configuration is known as a red giant, but after another billion years or so, the outer layers will dissipate, and the sun will be reduced to a comparatively tiny, small, dim, so-called "white dwarf." It will be a mere shadow of its former self. So our sun is not destined to become a glamorous black hole, it simply doesn't have the mass. For a star to become a black hole, it has to be about 20 times the size of our sun. A star *that* size will die in a much more dramatic fashion than our sun. We've all heard the term "supernova." A supernova is a massive explosion, an almost-instantaneous collapse inward that results in an ejection of materials from the interior of the star. The materials from a supernova? Mostly champagne. Oasis nailed it. A supernova is an awe-inspiring and extremely festive event. No, but it IS a violent, celestial cataclysm that forms a black hole in mere seconds and results in a massive shockwave, and even though the nearest supernova that we are aware of occurred gazillions of miles away—I'm nailing these technical terms—it was visible in the night sky on earth…many, many years after the actual event. The most recent supernova that was visible from earth resulted from the spectacular collapse of a so-called Blue supergiant star known as Sanduleak –69 202. I'm not making that up, and I don't even know what the joke would have been, but it FEELS like a bad joke. The 69 doesn't help. The supernova was observed by earth-based astronomers in 1987, but of course that doesn't mean it *happened* in 1987. Remember, these events are occurring mega-voltronparsecs away (that's more technical jargon) and this one in particular took place in the Large Magellenic Cloud, a dwarf galaxy adjacent to the Milky Way, 168,000 light years away, so those of us who were alive in 1987 were witnessing an event that happened 168,000 years ago. Or at least those of us who had clear skies and bothered to look up. I was too busy playing videogames and watching science fiction movies to bother caring about *actual* science and the miracles of nature. I was like, "Meh. I'll catch it later in National Geographic." But it is fascinating to think that when that Blue Giant went supernova, caveman were hunting mastodons during earth's most recent Ice Age. It took eons for that light to travel across solar systems and galaxies and the empty vastness of space to finally reach the earth and be completely ignored by young idiots like Shane and Duncan.

For those of you who *weren't* around in 1987, bad luck, it's likely that humans won't be able to view another supernova with the naked eye for centuries. Possibly the only benefit to being old: you and I lived through a supernova. Don't remember it, didn't see it, but we could always say we did, and it would be a credible claim…no one could prove us wrong. You young Insomniacs don't even get to lie about seeing a supernova.

Supernovas (supernovae?) are not rare in the universe, but visible ones are. "Before 1987, observers here on Earth hadn't seen the explosion of a distant star painted across the sky since 1604… [when]…Across the northern hemisphere, from Europe to China, [a] supernova appeared even in the daytime sky for three weeks. European and North American history knows the 1604 supernova as Kepler's Supernova, after the astronomer Johannes Kepler who described it in his book *De stella nova*."

So we're about ten or fifteen minutes into our journey to the black hole at the center of our galaxy, which means we still have some time left to prepare ourselves for what we're going to see. To be a little more specific we have 26,999 years, 364 days, 23 hours, and approximately 50 minutes. Just enough time for two idiots like you and me to actually sort of grasp the basic principles of astrophysics and black holes. And not just astrophysics; we also have to get a pretty decent foundation of quantum mechanics under our belts. So it's good that we have some time. Let's go ahead and define some useful terms:

The Event Horizon, apart from being a trauma-inducing film that scarred me for life, is also the border around a black hole past which nothing can escape, even light. It's like approaching a booby trap, once you place the event horizon you're like a fly that walked into the mouth of a carnivorous plant, the event horizon is a pair of jaws that snap around you and now you're never getting out.

Once any object or molecule or atom passes the event horizon, it is headed inexorably toward the Singularity; the innermost portion of a black hole. The singularity is the most fascinating and least understood element of a black hole; when a star goes supernova it ejects all of its champagne and then sinks down to an infinitely tiny point that is so small and dense that it technically consumes itself and thus doesn’t exist. You might be noticing a contradiction here, and we’ll get to that. In fact, the term singularity crops up a lot in math and physics and refers to where an equation returns an answer of infinity…which is a concept that doesn’t make sense. Whenever you run into an infinity in standard math, something has gone horribly wrong, and your theory needs to be revised and refined or at least error-checked. The laws of math don’t allow for singularities; a black hole is the celestial equivalent of dividing by zero. The singularity in a black hole is where gravity is so powerful that the laws of the universe break down, space time itself collapses; in fact a singularity is so unimaginably dramatic and inexplicable that it can’t be described by prepositions: there’s no “where” or “when” to a singularity. There is no specific location of the singularity itself, because it fundamentally ceases to exist in physical form, and because of the way gravity affects time, there is no way for us to determine the passage of time inside a singularity. In this way a singularity is a conundrum for scientists; it exists at an undefined point of misalignment between two major scientific disciplines: general relativity and quantum mechanics. They just can’t seem to agree on anything; they are ornery bitches; they do not like to play nice. *They're gonna get it on, because they can't get along.* I need to throw in more Mohammed Ali references. Among other disagreements, relativity says that all information that enters a black hole is destroyed, but quantum mechanics tells us that information-destruction is impossible. This is information in the scientific sense, and it can't be erased: "…the positions and velocities of all the particles, their spins and electric charges…the raw information of the system — everything there is to know about it — is preserved across time; it just gets rearranged, not created or destroyed." But Einstein would disagree. His theory of General relativity describes the universe as we see it on a daily basis via the interactions of the gravity of objects, while quantum mechanics describes the universe on incredibly small scale, and in particular the interactions and functions of the three non-gravitational forces: the two nuclear forces plus electromagnetism. And both of these scientific disciplines—quantum mechanics and relativity—have been validated and verified within their own fields, but the problem arises when you try to get them to come to a consensus on how a black hole functions. According to a Guardian news article: "Basically you can think of the division between the relativity and quantum systems as "smooth" versus "chunky". In general relativity, events are continuous and deterministic, meaning that every cause matches up to a specific, local effect. In quantum mechanics, events produced by the interaction of subatomic particles happen in jumps (yes, quantum leaps), with probabilistic rather than definite outcomes. Quantum rules allow connections forbidden by classical physics. This was demonstrated in a much-discussed recent experiment in which Dutch researchers defied the local effect. They showed that two particles – in this case, electrons – could influence each other instantly, even though they were a mile apart. When you try to interpret smooth relativistic laws in a chunky quantum style, or vice versa, things go dreadfully wrong." I didn't understand ALL of that, but from what I gathered there is a peanut-butter based conundrum in the scientific community. I'm actually pretty familiar with the idea of quantum entanglement because it's freaking fascinating, and also is beyond the scope of this episode, but suffice to say that quantum mechanics defies the laws of physics and time—at least as we previously understood them. Quantum theory tells us that electrons can affect each other instantaneously over vast distances without any delay, basically a phenomenon akin to teleportation of information…it's mind warping. So scientists are currently working on a theory of *quantum gravity*, which would marry the two fields and create a TOE, a t-o-e, a theory of everything. the ultimate unified theory that could help explain the mechanics of the universe. A TOE would explain all of the things. you might have heard of string theory, for instance, which is one particularly popular and controversial TOE that we will dive into in another episode; basically it posits that there is some form of energy or matter that is so tiny as to be indivisible, it is the fundamental substance of the universe, and it takes the form of a vibrating string. And the particular way that that each string vibrates gives rise to all of the of quarks and neutrinos and other subatomic particles that in turn make up the larger atoms and molecules that form our universe. It's like a guitar string that can vibrate at different frequencies to create different sounds, except instead of creating different sounds it's creating every goddamn thing that has ever existed or will exist. And you might ask "what is the string made of," to which a physicist would answer, you shut your whore mouth. It's made of string stuff. Universe material. Incidentally, the search for a unified theory is what essentially broke Einstein; he was increasingly resistant to the weird paradoxes that seemed to be arising from quantum mechanics, and eventually was pushed out of mainstream scientific fields, basically rendered irrelevant in his old age. In the 1940s he wrote to a friend, "I have become a lonely old chap who is mainly known because he doesn't wear socks and who is exhibited as a curiosity on special occasions." I totally understand Einstein's resistance to quantum mechanics. Because as we learned from Ant-man, the quantum realm is bonkers. Tiny little armies constantly warring, soldiers riding on tardigrades, it’s surreal and terrifying. Seriously, the reason screenwriters love the idea of the quantum realm is because it seems like absolute chaos where anything is possible. We talked about quantum entanglement, but there’s so much more; for instance, you’ve probably heard of Heisenberg‘s uncertainty principle, tjr idea that electrons, like photons, behave as both particles and waves. they don’t orbit a nucleus like a planet orbiting a star, and in fact can never be found in a single location, but rather their location can only be described as a probability of interacting with the electron at certain points. As a quick example of how bonkers this gets, here’s a description of quarks, a basic unit of quantum theory: “Quarks, which make up composite particles like neutrons and protons, come in six "flavours" – up, down, strange, charm, top and bottom – which give those composite particles their properties. The weak interaction is unique in that it allows quarks to swap their flavour for another.” If I were Einstein, I might be a little bit skeptical about a theory that completely undermined my own logical view of the universe and contained scientific terms like “charms” and “quark flavors.”

But the field of quantum mechanics has helped explain some properties of black holes that might paradoxically make them seem a little bit more logical. Like, the obvious question is where does all of the mass that is absorbed by a black hole go, but thanks to quantum mechanics, the generally accepted theory is that singularities *do* lose mass over time, and eventually sort of burn themselves out. The famous and famously disabled astrophysicist Stephen Hawking figured this out.

“According to quantum field theory, there is no such thing as an empty vacuum. Space is instead teeming with tiny vibrations that, if imbued with enough energy, randomly burst into virtual particles — particle-antiparticle pairs that almost immediately annihilate each other, producing light. In 1974, Stephen Hawking predicted that the extreme gravitational force felt at the mouths of black holes — their event horizons — would summon photons into existence in this way. Gravity, according to Einstein's theory of general relativity, distorts space-time, so that quantum fields get more warped the closer they get to the immense gravitational tug of a black hole's singularity. Because of the uncertainty and weirdness of quantum mechanics, this warping creates uneven pockets of differently moving time and subsequent spikes of energy across the field. It is these energy mismatches that make virtual particles emerge from what appears to be nothing at the fringes of black holes, before annihilating themselves to produce a faint glow called Hawking radiation.”

If Stephen Hawking is right, then the smaller the black hole, the faster it sheds Hawking radiation and burns itself out. “A **black hole** with the mass of a car would have a diameter of about **10 –24 m** and take a nanosecond to evaporate, during which time it would briefly have a luminosity of more than 200 times that of the Sun." Hopefully you blinked at that moment otherwise ouch. Speaking of tiny black holes, Let's talk about the size of a singularity. Which again seems to lead to contradictions. A black hole is not actually a function of huge mass, but rather a black hole is created when large amounts of mass are compacted into relatively tiny spaces; the real defining factor of a black hole is density. If you could find a way to compress a Toyota camry to the point at which its mass to volume ratio makes it so gravitationally intense that light cannot escape, you have a teeny tiny black hole that would flare out immediately due to Hawking evaporation. To turn the earth into a black hole, you would have to compress it down to around the size of a tennis ball. But how could gravity possibly compress matter to these scales…how could you conceivably fit the entire matter of the earth in such a tiny volume? Well, because matter is mostly empty space. Let's look at a single atom; if you blew it up to the equivalent size of a football stadium, at that scale the nucleus of the atom would look like a poppyseed in the middle and the electron shell would hover around the distance of the parking lot, and in between there would be nothing but empty space and the forces that hold those objects together. Your hand is made of atoms…

when you touch another object, the only reason your hand doesn't slide through it frictionlessly is because of the forces between and inside atoms holding them together—all of those electron shells repelling each other, etc—if those forces went away we would all immediately begin drifting through our clothes and the floor because we are basically clouds of mostly-nothing, the most infinitesimal volume of matter stitched together by the strong and weak nuclear forces. It's kind of a horrific reality to face. But that's why black holes can crush matter to such incredibly dense and compact volumes. They're breaking down the bonds between atoms and squeezing the tiny bits of matter together. So if we somehow found a way to exert enough force on the earth to compress it down to the size of a plum, it would become a black hole…and this is where things get really fascinating, because nothing would change. At least, nothing in the solar system. We would all be dead. But the black hole-earth would have the same mass as it does now, compressed into a tiny space because all of those forces separating atoms had been broken. Why would nothing change? Because black holes don't suck objects into them. They aren't celestial vacuums. The moon would continue orbiting the earth as usual. Let's look at this differently...if the sun were compressed down to a black hole, humans wouldn't die…for a while. Eventually the earth would become very chilly and very barren, but only because the sun wouldn't be sending out the sweet sweet warmth and radiation that we need. Our death would take a while, because other than the light in the sky going out, nothing else would immediately change. The earth and all of the other planets would continue orbiting the black hole at the center of our solar system. We wouldn't be sucked in, because even though the sun would be much smaller as a black hole, it would still have the exact same mass that it used to, and thus the gravitational forces would be identical. You can orbit a black hole indefinitely if you're in the right orbital trajectory.

Ok, we've been talking about black holes for quite a while now, I'd estimate around 27,000 years, that's how it feels, so we're finally approaching the black hole at the center of our Milky Way galaxy, good old Sagittarius A-star. If you look out one of the starboard windows the first thing you might notice is the vast emptiness of space and also a gargantuan blindingly bright spinning disc formed from gas and dust and matter, all of which has been pulled into the orbit of the black hole and pulverized into rotating plasma (not revolving) that is whirling around the black hole at close to the speed of light. this structure is called an accretion disk and it's very dramatic. The way accretion disc forms is pretty simple, every object moving through space has a trajectory, and when it is close enough to the black hole, it begins to be pulled downward but it’s still moving forward, thus it begins rotating, and when it encounters the accretion disc, it starts to grind against all of the other matter that has coalesced there, creating friction and heat… I might not have mentioned this, but the accretion disk is searingly hot, like tens of millions of degrees hot, but we’re going to pretend that our spaceship is built to withstand temperatures hotter than the surface of the sun. Because why the hell not. It’s my party I can do what I want to. Our spacecraft name makes even more sense now, hubris indeed. Btw, Searching for those bright accretion discs is one of the ways astrophysicists can find and detect black holes in space. Paradoxically, while singularities are completely invisible to the naked eye, black holes are actually some of the brightest objects in the universe because of their accretion discs… when those accretion discs reach a certain level of brightness, they become known as quasars, the brightest objects in the universe. The brightest quasar so far discovered shines with the light of 600 trillion suns. Bring shades. I want to wear those Venetian blind shades when I stare at 600 trillion suns, I feel like those would set the appropriate tone. So we’ve passed the accretion disk and somehow didn’t get blinded and flash fried by light and heat and radiation, because magic spaceship, or at least the magic of imagination, and now we’re approaching the event horizon. We are officially falling into the black hole. But we still have a chance to survive, because between the event horizon and the accretion disc is an area called the innermost stable circular orbit. I’m betting you can’t guess with that means. Pretty on the nose. If you’re trying to visualize the distance of this orbit from the center of the black hole, it’s about three times the Schwarszchild radius. You’re welcome. The Schwarzschild radius is the distance from the singularity to the event horizon…got all that? So we’re just going to chill and orbit here for a while, on the rim of the event horizon, just kind of edging as we like to say. We’re not taking the plunge quite yet, because there are some cool things to see here. Like the back of our own heads. Because what you will usually find orbiting in this final stable orbit, is light. There is a ring of photons in this orbit and if you were to somehow stand in the stable circular orbit you could theoretically see the back of your head because the photons would be spinning around in a circular motion. Due to the orbiting light, this area is also referred to as the photon sphere. Somehow we’ve made it past the molten accretion disc and we are in the innermost stable orbit, we didn’t come all this way to just fry ourselves and stare at the back of our heads. We’re going in the black hole. As we pass the event horizon, the immense gravity of the singularity begins compressing us horizontally and stretching us vertically, a phenomenon known as spaghettification. That’s a real honest to God scientific term, my phone didn’t even spell-check it. We would eventually be pulled apart as our atoms are torn asunder, we're being compressed down to virtually nothing as the space between and inside our atoms is crunched and eliminated. But interestingly, an observer wouldn't witness us being shredded by gravity. Think about it, as we approach the event horizon, fewer and fewer light waves are able to actually escape the black hole to reach the eyes of an observer, and after we pass the event horizon, none of that light is coming out. If they COULD see us, we would also seem to slow down and then freeze in time, and that's because the gravity inside a black hole is so great that it bends spacetime, a phenomenon called time dilation. time is affected by both of Einstein's theories, general relativity and special relativity. General relativity tells us that times slows down closer to an object with a large amount of gravity. This is even true on earth; clocks on the space station move a tiny bit faster than clocks on earth, and GPS satellites have to actually be adjusted to account for this effect. time is subjective...or you might say kind of generally RELATIVE. However, on the inside of the black hole we wouldn't experience time slowing down, the torturous stretching of our bodies would happen in real time for us, yet time is passing incredibly slowly relative to the outside world. The outside observer would never see us reach the singularity, but if you could look out from past the event Horizon of the back hole (and technically you can because light is still pouring in) you would see the universe around you moving in fast forward. If you've ever seen interstellar, which I watched again for this episode, time dilation is why every hour on the ocean planet is seven years back on earth. Because the ocean planet is orbiting a super massive black hole called Gargantua.

I hate to be anticlimactic, but that's the end of our journey into the black hole. We're dead. It was probably very majestic, and also short and briefly painful and then relaxing for all time. it's also the end of our episode. I like to end on our collective demise. Preferably humanities, but in this case you and I will have to do

We have new reviews!

Not much to say

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This is one of the few podcasts I keep finding myself come back to. Always an interesting topic backed up by great chemistry.

Richård via Apple Podcasts · United States of America · 11/28/23

Split

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I've been listening to this podcast for over a year now and I've had a lot of laughs. However, not a huge fan when they make comments objectifying women's bodies. Hoping to hear less of that, but still a fun show to listen to while driving.

AllisonPsych11 via Apple Podcasts · United States of America · 11/20/23

Seabunny • 7 days ago
I may be Christen but this podcast is a banger!

And hey, that's valid. I appreciate the five stars and I appreciate the constructive feedback. We can do better. I don't know if we can stop objectifying in general, so maybe we just need to objectify more men. Even it out. We've talked about male bodies, any longtime listener to the show knows that we are hetero horny for Chris Evans, Chris Hemsworth, Henry Cavill and Ryan Reynolds. Those guys have been thoroughly subjected to the male gaze.

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Relativity versus quantum mechanics: the battle for the universe | Physics | The Guardian

10 Questions You Might Have About Black Holes - NASA Science

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