The Other End of a Black Hole

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At first you wouldn't notice anything and then suddenly everything would change radically and violently imagine yourself 500 years in the future you're sitting in a ship zipping through the silent empty void of outer space you're traveling to explore a black hole up close for the first time in human history.You're very lucky to be able to do this.

For centuries the prospect of traveling to a black hole was absurd the closest one is nearly 60 million billion kilometers away but great advancements were made in space travel and cryogenics and here you are you're traveling to explore a black hole and you're about to make a very big mistake but we're getting ahead of ourselves what is a black hole really everyone here is either sitting down or standing as a couple of people are standing that might not sound like a profound statement but cosmically it is and if you're watching this video afterwards chances are you know maybe at the home or the office chances are you're standing at a table or sitting on a chair or perhaps lying on a sofa no matter who you are no matter your gender or skin color you all have one very important thing in common you're not currently floating around the room why are you not floating because of gravity of course gravity is the force of attraction between any two big objects like between the moon and the earth between the earth and you but behind that simple simple statement lies a series of very profound insights that require us to completely change our understanding of the fabric of reality so the ultimate question underneath it all is what causes gravity so physics as you know this is the type of question what causes gravity this is the type of question that keeps physicists up at night because physics is among other things as you know the search for mechanisms the the you know reasons or uh or explanations for why certain things happen the way they do the why and the how and if a physicist comes to you and says what and asks you what causes x phenomenon and you tell her that's just the way it is she will be very dissatisfied with your answer and so for the longest time the question what causes gravity was not so well understood and even you know a fairly bright guy known as isaac newton uh even isaac newton someone who who managed to describe gravity quite well in the 1600s even isaac newton at some point had to admit i don't know what's going on so in the scallion general he says i have not as yet been able to discover the reason for these properties of gravity from phenomena and i do not feign hypotheses he's saying yeah my equations work really really well but the why i have no idea why and for the long time people would say okay well maybe gravity is just like a universal force and that's just always the wind the way it is and if you think about that that's a little bit too close to that's just the way it is it is not satisfying at all and so what is that what is the mechanism that keeps you seated in your chair and that keeps the moon uh orbiting around the earth like that for the longest time again this was not understood until albert einstein and albert einstein needs no introduction in 1915 he finally came up with general relativity a general theory of relativity and came up with a mechanism that explained how gravity actually works and it required us to completely change our perspective on the nature of reality and so the question is what for example when an apple falls from a tree what is the apple falling through okay the atmosphere so maybe that's a bad example but what about the moon what is the moon falling through not really anything right but it's falling through empty space but what is space again the concept of space for a very long time was this notion that it was sort of like you know there's different ways that people thought about it right but the concept of space for a very long time you could think of it as the sort of background grid upon which things happen right so the the space is space is not real in the sense of you know like a moon or the earth or you know like a table or something like that but if i want to i can impose a grid upon it so that i can describe things in the physical world in a better way in a more convenient way right so i can impose a grid like for example lines on a chalkboard if i want to make a grid so that i can better describe some you know planets that are doing something with arrows i don't know what that was i just decided to draw it in a moment's notice but the uh but you know that grid is there for so to help me with my calculations right and you know it's sort of like an abstract thing and it's so abstract that if i wanted to i could actually choose a different coordinate system if i wanted to right and as long as i um as long as i am consistent about what i'm talking about then it's totally gonna be okay right and we'll let this guy finish his work here right great very good oh that's good too oh beautiful he's an artist um but but again so you know the the the so space in a sense is this background grid it's like these these this metric lines that we impose upon things so that then we can describe physical phenomena that are going inside but it's not real it's not as though i like i draw a circle on the the blackboard it's going to change the blackboard or the blackboard itself doesn't change the circle but in fact that's so you might think that space is like that space is nothing it's just some sort of like a background thing it turns out that einstein pointed out that this is absolutely not the case einstein pointed out that in fact there's a completely wildly different way to think about it in fact the way that gravity arises the way that gravity comes into existence the way that the force of gravity arises is due to the presence of the fact that the presence of a certain amount of stuff within a certain volume of space actually warps and bends the fabric of space itself so in that sense space is actually something malleable it's bendable and this is a completely this is a completely different way of thinking about the world it was not just a you know a small step forward it's a complete sea change with the way that we understand the world and so now because of that so for example if i put something that has a certain density so that you can think of space in this sense as more like a instead of just a completely empty space it's more like a rubber sheet right and if i put like something heavy on the rubber sheet it actually deforms the sheet if i have nothing there the regular rubber sheet and we're all stretching it tight if i flick a little marble across there the marble goes in a straight line right but if i put something heavy there like a bowling ball or this yellow thing and then if i now that if i push something if i flick a little marble or something it actually from the marbles perspective it's going in a straight line but from a larger perspective it's actually falling toward the thing that is curving the fabric of space itself this was a wildly different way of thinking about the universe so therefore we have our mechanism the moon and the earth for example orbit around each other because each one is falling into constantly this the curved spacetime of the other due to the presence of energy and matter density in in space itself this is just mind-boggling you know and it still is to me and it was at the time too so this was a very very radically different way of thinking about the world but it gets worse because it turns out that not space is not just bendable it doesn't just bend it actually flows too space is something that actually can move parts of space can actually move compared to other parts of space and this is has wild consequences right so what that means is that so this is basically comes out of the the equations of general relativity so if you have something that has a lot of gravity you can actually have space that's bending it creates a kind of a sinkhole in space itself but if there's a lot of stuff packed into a small enough volume space itself starts to flow toward the center of that volume so for example if you have the sun it's a certain has a certain amount of density the denser the object the deeper the sinkhole and the more space starts to bend toward starts to flow toward the center of this volume so the sun for example uh warps spacetime a certain way you can think about the the extent to which this space is flowing toward the center of any of these objects in the sense of uh how fast you would have to go to get away from the surface of one of these things right so for example if you wanted to get away from the earth you you know we know that you have to go pretty fast to get away from the surface of the earth but we know that it can be done obviously if you wanted to get away from the sun you'd have to travel 50 or 60 times faster than that and if you wanted to get away from a neutron star you need to travel at something like 60 percent of the speed of light given the fact that we the my astrophysics colleagues estimate that the the fastest speed that a human could possibly go without getting killed is something about half the speed of light and as humans the fastest we've ever gone in anything i think is something like 0.000 percent of the speed of light you're not going to get away from a neutron neutron star with our current technology but think about what this means if you take this to its logical conclusion right if i take a certain amount of stuff in space it bends space and space starts to flow a certain amount if i put more stuff into his fixed volume it starts to bend and flow even more take that to its logical conclusion if i put too much stuff into a fixed space space will bend and flow so quickly into the center that no matter how fast i move i'll never be able to escape this flow and this is our black hole you can think of a black hole like an extremely strong water drain where the water is the fabric of space itself imagine you're a fish in the water if you get too close to the drain the water will be flowing inward faster than you can ever possibly swim and even if you swim at your fastest possible speed you'll be sucked into the drain likewise if you stay far enough away from a black hole in space you're okay but there's a point of no return called the event horizon beyond which space is flowing into the center of the object faster than the speed of light so not even light can escape from inside of this black hole but if that's the case and so you probably heard these things i understand that for the last you know 10 minutes or something i've been saying things that a lot of you have heard a million times before but what does that really mean like if that means that space is flowing faster than the speed of light inside this black hole beyond this event horizon this point of no return what does that really mean what's actually going on inside of a black hole that's the zillion dollar question if you can find the answer to that you will have about 10 nobel prizes i think so two things probably jumped out at you when you see an image like this a gif like this right so the first thing is that thing in the middle a singularity so you probably heard the word singularity before but in a physics sense what this means is that there's a sp point in space where you have infinite density and infinite curvature of space i don't know about you but i have no idea what that means and i'm a physicist so i have no idea what it means to have actually to you know to actualize that in the real world what does it mean to have a point that has infinite density and an infinite curvature of space probably what this means is that there's something we're missing so if you look closely at the mathematics of general relativity and you should always look closely at the mathematics you see these things like singularities that point let's jump out in the equations like this and typically when you have something that shows up in your your equations that makes no physical sense that's typically the universe's way of telling you to think a little bit harder and that you're missing something there's something that needs to be put in to avoid these sort of catastrophic nonsense things so the other thing you probably noticed about this is that inside the event horizon of a black hole if space is flowing faster than the speed of light if you went to travel to a black hole to study it up close and you should definitely want to do this because it'll be amazing you probably should stay away from the event horizon because if you went inside there's no way for you to ever tell the rest of us what you learned because there's no way for you to send a signal outside of the event horizon it's a one-way trip into a black hole so that's the two things that you have probably have you know that have jumped jumped away from you so again if you wanted to go to a black hole to study it up close and you should definitely want to do that you definitely want to want to stay away from the event horizon and the first reason of course is that scientific reason like i said you would be a very very bad scientist if you go one way into a black hole and you could never send your data back to the rest of the community right that's a very that you're being a bad scientific you know bad scientist for the community but the second reason you would want to stay away is actually existential because the conditions inside of a black hole are such that the gravitational conditions will be such that it's likely with a certain size of black hole it's likely that if you go into a black hole the gravitational force on say your feet will be much much different from the force on your head and you might get stretched into spaghetti so for example the fish in the water drain if a fish got too close to a black hole it would probably be stretched into something resembling fish spaghetti very quickly so existentially you'd want to stay away from the black hole as much as you could so but that's for black holes of a certain size so for example smaller black holes are kind of medium-sized black holes yeah the gravitational conditions as you go in will be so violent and so crazy that they would probably rip you apart or stretch you into spaghetti like this but there's a big caveat here and we'll get to that in a moment but the other thing you should be asking yourself is okay the thing i mentioned and anytime your your mathematics tells you something that's sort of nonsensical and doesn't make any sense and you're like wait a minute this probably doesn't exist in the universe the singularity you should also ask do we really know that black holes exist maybe this is just some kind of nonsensical thing that pop out of some equations that humans are using but nature wisely avoids using because it makes no sense so it's not just a mathematical oddity that our universe avoids black holes were a prediction for many years so take go back to 1915 like 10 years before einstein had completely changed everything with special relativity brownie emotion all these things everybody's going crazy then in 1915 everything changed again the guy completely ruined all of everybody everyone's perceptions about the universe twice within 10 years so this people were catching up with this and the first some of these first predictions that were coming out they didn't make a lot of sense people like okay we need to check this thing we need to check this thing there's also this solution that you found that led to this concept this object known as a black hole which is very scary and weird and for the long time for decades people like okay well that's sort of an odd thing maybe you know i don't i don't know how we're gonna gonna detect one of those things so maybe we'll see those in a uh you know in a few years or something so it was a very strange prediction for decades and decades until the 1960s when in the 60s and 70s astronomers noticed something weird going on near cygnus x1 and if you can't spot the black hole on this object you're there's no you should not be feel bad because that's where the black hole is hiding there's a black hole hiding in that light spot so cygnus x1 is actually a is a is a double double system there's a black hole with a blue giant supergiant star next to it and this is an artist's rendition of what the of what cygnus x1 looks like so it really is this and in fact in the 60s and 70s astronomers started to see these hot uh this extremely energetic x-rays and gamma rays that are coming away from this thing that wasn't radiating itself but it seemed to be eating another star that was next to it and these these signals matched almost exactly what you would expect from a black hole doing this so this is an artist's radiation of course you might also ask okay this is just one example but we also know that we can so we can't actually see black holes directly right because no light can emerge from them but we can see other stars orbiting completely dark empty spots in space there's obviously something going on there in the middle though even even in the middle there even though there's no star that you can see and as of so the the evidence for black holes is mounting and mounting and as you know as of 2019 we can actually see the hot gas from around a black hole as it's being as it's being twisted around this black hole and this is from the event horizon telescope collaboration from 2019 one of the most amazing images that humankind has ever produced and this is an m87 55 million light years away so black holes are really real indeed and they're not even that rare you know it's it's strange because the universe seems to love these twisted vortices there's there's a big one in the center of nearly every large galaxy we've seen and our own in fact the closest uh confirmed black hole is that cygnus x1 which is about 6 000 light years away given the fact that our milky way is about a hundred thousand light years across six thousand light years is not that far away our universe our milky way seems to be sprinkled with smaller black holes as well and there even could be a mysterious black hole even shockingly closer to earth in the outer edges of our solar system several big rocks seem to be orbiting in strange ways some astronomers think there's a new planet planet nine that could be responsible for these wobbly odd orbits but we see no evidence of a visible planet so what if it's not a pl the reason we haven't seen it is that it's not a planet but in fact is a tiny black hole about the size of an apple that was born just a little bit after the universe was formed 13.8 billion years ago and then floated around our universe for billions of years before finally getting stuck in our solar system so an apple-sized black hole heads up so an apple site oh and i wanted to show you this thing too so actually a couple of the physicists that proposed this idea because some other physicists that i know came up with the idea that maybe there's a black planet nine then some other physicists that i know jacob schultz this guy he's like well wait a minute what if it's actually a black hole in their paper if you go to their paper in the auxiliary supplementary material that's typically the place in the place in a paper where you put like really really detailed calculations that nobody wants to deal with or you know or like the extra part of your data the copious list so in case somebody wants to replicate what you did it's the really boring part of the paper these guys decided to put a life-size version of what the black hole would look like so this is if you printed the paper that's right there on the on the on this on the page it's quite cool so an apple size black hole could you make a black hole yourself so if you want to know what it takes to make a black hole just grab your textbook on gravity i assume you all have a textbook on gravity on your bedside table like i do and find the black hole equation it'll tell you for some given amount of mass how small of a volume you have to pack it in to make a black hole for example to make a black hole out of the earth you need to pack the entire thing into a volume about the size of a blueberry most black holes we know of of course are much larger than this with masses uh for example the one at the center of our galaxy has a volume has a yeah i think a diameter that's something like one-third of the distance between the earth and the sun but with a mass that's like several million times that of the sun and there are much much larger black holes out there too with masses that are billions tens of billions of times that of the sun and with volumes that would come encompass our entire solar system but it's really actually that easy the equation is fun we can actually do some fun things with this equation we can just take any mass and look at it so this is our equation let's imagine we wanted to make a black hole out of a proton a proton is already very very small 10 to the power minus 15 meters completely diminishing already right if you wanted to make a black hole out of a proton you need to pack it into a volume that's 10 billion billion times smaller than the planck length given that the planck length is the smallest physically meaningful distance that quantum mechanics allows us to define a proton is safe.

You're never going to make a black hole out of a proton what about you can we make a black hole out of you if you want to make a black hole out of you we would need to pack you into a volume that's 110 billionth the size of a proton given that this is a thousand times smaller than the current most powerful distance resolution on earth which is the large hadron collider you are also safe we're not going to make a black hole out of you what about the sun if you want to make a black hole out of the sun you'd have to smash it into a diameter into a sphere that has a diameter that goes from about westminster abbey to dalston okay so i know that sometimes during you know high tourist season trafalgar square gets so dense that it sort of seems like it would make a black hole but no it's not ever going to be close to the volume the density you need to make a black hole like you know packing the entire sun into dalston what about something really big what about the observable universe so recall that space bends and flows right we established that earlier we know that space is not something that's static it actually is malleable and it bends and it flows this happens also on large scales you may have heard the statement a zillion times before the universe is expanding and it's true we know that the universe is expanding but expanding into what nothing space itself is expanding for example two galaxies in our solar system or sorry two galaxies in our universe are like two pins stuck into this rubber sheet then the rubber sheet is being pulled from all directions from the perspective of an ant on the sheet nothing happened to make the pins move space itself is moving at the sheet and the distance between them is increasing so we know that this is happening to our universe and because of that we also know that the the particular way so you know for example if you uh if you because of the particular way that the universe expanded right at its birth we also know that there are parts of the universe that are currently unobservable to us.

They are outside of the so-called observable universe this this is a consequence of the way the universe expanded right at the moment of the big bang right before the moment of the big bang in fact so there are parts of the universe that are so far away that we can't see them okay so the observable universe is defined as this sphere that's around you every single one of you in fact has a slightly slightly different observable universe there's a sphere around you that's composed of all the stuff that has had a chance to send a light signal that you could receive but beyond that we have no idea how big the entire universe is so the observable universe right now is 93 billion light years in diameter but the entire universe we have no clue it could be infinite in fact it could be something smaller we don't know so we can't it's very difficult to to estimate the amount of stuff that's in the entire universe but you know my astrophysic physics colleagues are quite good we can estimate the amount of stuff that's in the observable universe right so if we take all the stuff that's in the observable universe right we add up all the protons all the neutrons all the electrons all the stuff that makes up you and me and potatoes and then we also add up all of the uh the neutrinos the every single one of you has about 10 trillion neutrinos from the sun zooming through your thumb every second we add up all of these particles as well then we add up all the dark matter and we add up all the photons and we add up all the gravitational waves we get an enormous number we get something that the universe is probably the estimated total mass is something like 10 to the power 54 kilograms then if we look into what this so so again we just use this equation we can figure out what it would take to make a black hole out of the entire observable universe and if you do this calculation you find that it would take a diameter that's three times the diameter of the current observable universe let me double check my calculation here okay so okay so okay astrophysical numbers are you know subject to uncertainties maybe we got the number a little bit wrong so let's imagine that even the number is twice as much as we as the estimate here let's imagine that in fact the universe is something like uh 10 you know 5 times 10 to the power 53 it's half of what we thought it was this will make more sense right so then if you if you wanted to make a black hole out of the entire observable universe you need to pack it into a sphere that's about a little larger than the current observable universe do we live inside an enormous black hole when i first came across this calculation i was dumbfounded i it made no sense is it possible that the interior that our entire universe is the interior of an enormous black hole i mean i it doesn't make any sense because i thought the black holes you know from science fiction to these twisted vortices that suck in entire stars and they make you know christopher nolan movies crazy you know things like that so i thought that's what black holes were and i this made no sense to me it turns out that it depends upon so you know i thought that it makes no sense that we would be inside of a black hole because you would just get twisted you would get torn to shreds just like we talked about it turns out that as long as the black hole is large enough you would be okay you would be okay inside the event horizon of a black hole so it depends on the size so for example if you happen to fall into a black hole that was the size of the one that would go around london the solar mass black hole within you know from westminster abbey to dalston you'd have no chance you would be ripped to shreds immediately but with a large enough black hole you'd be okay it would still be a one-way trip once you cross this event horizon there's no way for you to go back out but it's entirely possible that our observable universe right now exists on the interior of an enormous black hole this is very weird i admit but black holes are more than astrophysical oddities if you think about it they're actually profound statements about the limitations of knowledge so what is a black hole actually doing think about what it does right a black hole separates the world cetera it separates the physical world into two regions right you have the inside the black hole and you have outside the black hole and this event horizon becomes a barrier a border this thing that's always in the distance right that you can never reach no matter how quickly you travel you'll never be able to get to that thing right we know that black holes eat things and grow so for example that big that artist rendition i showed with the swirling black hole sucking in the blue giant that black holes or event horizon grows at the more stuff that it sucks in so we know that that event horizon is growing if you're on the inside this thing would be growing too so this horizon think about what it means to be inside of a black hole this you'd have this point of space this region of space that you could never get to and it's always receding from you a horizon right so so yeah just to you know show so you have stuff that's falling into the into the black hole the event horizon grows right but think about what it then means for you right now on earth think about your situation right now here on earth if you look out into space there is a horizon very very far out away beyond which we cannot see but we know there's stuff there but we can never possibly see and no matter how quickly you travel you'd never be able to get to it that's remarkably similar to what you would experience on the inside of a black hole and it turns out that the mathematics and again you should always look closely at the mathematics it turns out that the mathematics of the interior of a black hole is almost identical to the mathematics of the exterior of the black hole you know have to do some stuff with the infinities going to infinity versus zero but yeah trust me it's you know trust me you can look it up in your textbook on gravity that you have on your bedside table but this is you know this is actually what is going on mathematically it makes sense as well so there's also another reason to think that this is oh so yeah and for example just i wanted to show off my nice animation here right so as stuff come on show me here there we go yeah okay it's the same thing right you have things that are coming so this this uh this this edge of the observable universe is getting bigger and bigger and for example if you were able to live for you know hundreds of millions of years there would be stuff that would be coming into your view that you couldn't see before so this is very similar to what you would experience inside a black hole so the other thing that's interesting about this right is that we know that the universe is expanding and then if you run the clock backwards like the youtube slider of the universe you just run it backwards right eventually that means that everything far far back in in time if everything's expanding now everything had to be packed into a tiny dense little point at some point and that's that's kind of similar to what you would expect from a singularity in the middle of a black hole so does this mean that our universe which was born from a black hole 13.8 was born from a big bang 13.8 billion years ago was our universe actually birthed from a black hole in another universe and does that mean the black holes in our universe are doing the same thing every black hole could be a seed to a new universe and i see the looks on your faces as well and i completely agree with you because at the end of the day i am an experimentalist and these ideas are wonderful i love these fantastic ideas i love to read about them i love to have theorists go crazy and show me their new papers and look this is happening at the end of the day i need to see some evidence and it currently turns out there is scant possibility for us to gather any evidence for this hypothesis in the foreseeable future so at the end of the day so again this is this is not this may sound very science fictiony right but it's actually at the end of the day you can find solutions again going back and looking closely at the math you can find solutions that show that inside of a black hole it doesn't have to be just a singularity point right that you know that makes no sense it's like this mathematical nonsense in fact as you've heard and again i mentioned christopher nolan movies right in fact there are solutions that if you go into a black hole it's not just a point but it could be a so-called wormhole or an einstein-rosen bridge and in principle this wormhole could be a wormhole from here from our universe to some other point in our own spacetime within our own universe or it could be to another universe within a multiverse or it in fact could be a little seed to another universe but again i'm an experimentalist how are we going to test this here's the problem can we test the universe in a black hole idea first of all the way you test it is to go into a black hole and find out as we mentioned that's a one-way trip i really really thank you for doing that but i'm never going to be able to learn what you learned so that's you know it's a one-way trip second there's no distinct there's no experiment i can come up with currently that would enable me to distinguish that hypothesis from some other hypothesis right so if i say oh yeah well you know we live in an enormous black hole okay that's okay you know part of the equations show me that that's indistinguishable from our current experience but how am i going to distinguish this from some other hypothesis there are possibly some ideas floating around but they're not so good third what does it mean for me to contact another universe i would love to for someone to give me a coherent answer to this question because the ideas that come up make no sense for example what if i have a measuring device here in my universe that works really really well like a ruler or you know some kind of extra device or something and i take it into another universe where carbon atoms don't exist the measuring device is useless so this is just one extreme example but at the current you know currently there's not a way for us to even test this hypothesis so i love these ideas i love them i want more ideas like this but i also want ways to be able to test them however i am actually excited for the future because i know from history i would never want to underestimate humanity's ability to come up with ways ingenious ways to test impossible ideas so i'm hoping somebody in this room will actually end up studying physics and find the way that we can test this hypothesis so again at the end of the day we you know we don't have a way to currently test this but one thing we haven't covered at all so far is the fact that is how black holes come into existence because if we knew that in principle we could design an experiment to make some or maybe to you know to figure out how we could study this in a sort of indirect way we don't have to directly go into a black hole just like we don't have to directly and over the higgs boson we discovered it in the lhc you'll never hold the higgs boson in your hand but we can indirectly see what the the higgs boson exists based upon its decay properties things like that so maybe there's an indirect way to understand whether or not we live inside of a black hole but first we need to figure out how to make black holes okay so how does the universe make black holes how does the universe make some these twisted vortices these things that are so dense that they nearly puncture the fabric of space space-time well one way is when an enormous star dies after billions of years a star can exhaust the fuel it needs to burn and when the final hurrah it explodes and then with no more nuclear fusion to push it outward gravity wins and the whole thing collapses in on itself and this collapse can be so severe that it creates a black hole so you you know so what you can see from this is that you need and also so let me mention the apple size black hole so the gentleman's black hole right here that he's holding so these apple-sized black holes could in principle be something called primordial black holes that means that these could be black holes that were caused right back near the moment of the big bang right when the universe was born and the particular way that the universe expanded could have popped a bunch of these primordial black holes into existence and they just sprinkled around the universe for billions of years right so you can see that you need an extremely violent event to make a black hole that's why you can't make a black hole out of you or an apple or anything or the earth so is it possible that we could make black holes where i work at the large hadron collider so the large hadron collider is a 27 kilometer circular tunnel on the border of france in switzerland about 100 meters underground and in this tunnel we use superconducting magnets colder than outer space to accelerate protons to almost the speed of light and then we slam them into each other millions of times a second on the particle level this is a pretty violent event and in fact it's theoretically possible that we could make tiny minuscule versions of black holes that would evaporate immediately but i know what some of you might be thinking i see some looks on your faces as well let me make very clear to you there's no way we're ever going to make a regular black hole at the large hadron collider for the following reason you should actually know this by now since you've seen the first you know the first half of this talk right black holes are all about gravity right and so we're colliding protons together at the large hadron collider right protons get close to each other and they start to experience interactions forces we only know of four four known forces fundamental forces in nature right we have three that you know the strong force the weak force the electromagnetism and then gravity right but they're not all the same strength especially at the particle level when two particles get close together some are more more powerful than others so from two when two protons get close together the strongest force we know of is called the strong force it's a very nice name for it so let's give that a pow a for a strength of one compared to the strong force the force of gravity is 10 to the power minus 39 there's no possible way we in fact we completely neglect this.

When we do calculations at the large hadron collider of proton collisions the force of gravity between two protons is completely negligible compared to the others so there's no possible way we're making it gonna make a black hole out of uh two protons at the large hadron collider oh and i want to show you show off my nice animation here pow black hole no just a hammer at home but recall that the reason why well i'll put it this way the reason why we physicists are obsessed with and fascinated by black holes is because they could help us answer one of the biggest open questions long-standing questions in physics and this is the question as to whether gravity and quantum mechanics have anything to do with each other in physics we have two fantastically good theoretical models that have withstood essentially all of our experimental tests the first is called general relativity which we talked about which governs how how gravity works on very large scales and the other is called quantum field theory quantum mechanics which governs the world of the very small each of these by itself ranks among the most impressive intellectual achievement of humankind but there's a problem when we try to naively combine these two theories hoping for a more fundamental theory of the universe everything breaks we get nonsense answers like infinite energies or probabilities greater than one.

When this happens like i said this is the universe's way of telling us to think harder and it's entirely possible that the reason that we haven't we don't fully understand how gravity and quantum mechanics work together is that in fact there's something we're missing about the fabric of space itself so one of the ways that gravity because basically the question is why is gravity so weak compared to the other forces why is that if you were some kind of you know logical uh logical universe making person you would never make it that way it makes no sense that you have one force that's all the way down here and all these other forces that are up here right so one of the ways that this could happen is if in fact our understanding of the fabric of space needs to be needs to be changed in fact one of the ways that we could be missing the fact that gravity is so weak compared to the other forces is if gravity in fact exists in extra dimensions of space that are tiny and curled up at every single point in space and so gravity in fact leaks into these other dimensions and if we had some magical measuring device that would allow us to somehow measure gravity in these other dimensions we would measure it as being just as strong as the other forces this would be amazing and and you know to give a few more details so basically what it means is that the planck scale so i mentioned this thing called the you know the the the plunk energy or the you know the the plunk length and things like this basically this is this is a length and an energy and a time scale that is sort of a limitation based upon the constants of nature and what it means is that the radius of a of a sphere for example again remember that it takes a certain amount of stuff you have to pack into a certain volume to make a black hole right but that's that radius again that's that schwarzschild radius the radius part in the equation that i was showing you right that radius the definition of a radius changes when you have extra dimensions of space and in fact what it can do is it can make this plonk level this planck scale where it which is the place at which gravity and quantum mechanics have something to do with each other it could actually bring it down it actually lowers what this this planck scale is and it makes it so in principle you could make a black hole out of two small things with very very small amount of with a much smaller energy so this is entirely possible but what it means is that we're not going to make a regular black hole at the large hadron collider in principle we can make a tiny minuscule object that would snap it and pop into existence and would snap into the extra dimensions and wobble around a bit before then decaying and evaporating into things that hit our detector and you know this is a so this is a not an artist's tradition but there's a simulated version of if we were to make a miniature black hole at the large hadron collider it might look something like this so again this is uh you might be a little bit uh weirded out by this that we might be making miniature black holes but just to you know i don't want to go i'm getting a little bit late here but i just wanted to show that in fact this should is nothing to worry about because even again if even if we make a miniature black hole at the large hadron collider it would evaporate immediately one of these miniature things and it would be fantastic if we did because it would help us understand gravity how gravity and quantum mechanics work together and help us maybe answer one of these biggest open questions in science but if you're still worried don't worry at all because the large hadron collider we use very high energies of the large hadron collider but we're no match for nature nature has much higher energy collisions going on all the time just a few kilometers above your head so above your head right now are cosmic ray protons coming in from outer space all the time and they get they come into the upper atmosphere and they smack into the atoms that are up in in the upper atmosphere and so if these things do if these things uh these collisions are happening all the time at energies that are much higher than the large hadron collider and you've never actually you've never experienced a quantum black hole that suddenly comes into your body and decays and eats you up this has never happened so this if this has never happened in the upper atmosphere it's not going to happen a large hadron collider and i think for the sake of time i'm going to go through these oh show off my nice animations so they can actually do different things if we saw these quantum black holes these miniature black holes in the upper atmosphere they would do certain things blah blah they could in fact pass all the way through the the earth and go through the other side or in fact they could decay right near the surface of the earth and we might be able to detect these so in fact there are experiments they're looking for for things like this but okay even though we could potentially make miniature black holes at the large hadron collider we haven't seen any evidence of them yet oh this is very sad but maybe we just need a bigger collider discussions are currently underway for the potential successor to the large hadron collider the future circular collider which would be a hundred kilometers around and could reach energy seven times that currently used but will that be big enough maybe quantum gravity this the holy grail this thing we've been searching for maybe quantum gravity is waiting for us on the moon so last time i was here at your illustrious institution i gave an entire talk about the concept of a big bang machine on the moon and i took talked in very kind of rough details about what it would take to build a collider that goes around the moon and why we'd want to do this and just a few uh in just a few months ago in fact a colleague and i finally wrote a paper about this concept and it turns out so you might think it's like building a you know so a colossal a colossal collider around the moon will be 11th out where the large hadron collider is 27 kilometers around the circular collider on the moon would be 11 000 kilometers around and could reach energies a thousand times that currently used and i see the looks on some of your faces too so building a collider around the moon to potentially make miniature black holes on the moon is this crazy and in fact i did i went through the exercise with a colleague of mine and it turns out it's not crazy in fact there's no showstoppers to building a circular collider around the circumference of the moon the all the technology is there all of the science is there it's just a matter of scale it's just a matter of development and scale a circular collider on the moon sometime in the 22nd century is something that might sound impossible but it's just regular impossible it's not impossible and possible and regular impossible we can do regular impossible is only impossible right up until the moment somebody makes it possible so is that going to be big enough though maybe a moon collider is not large enough for us to make these miniature black holes again the whole point here is that we wanted to understand how what like what's actually going on inside of a black hole how did they get made maybe we could find a way to make them in the laboratory so we could understand them the place where we really really really want to go to understand this completely is called this planck scale right and the plunk energy again if these extra dimensions don't exist then the planck scale is something extremely high this is an energy at which gravity and quantum mechanics must have something to do with each other again the larger collider you build the bigger the energy the better chance you have to discover things like miniature black holes so but the problem is to make uh a planck scale uh planck scale collider uh by some estimates you'd have to build a collider that circles around the outer edge of the solar system clearly we're going to need some major innovation to do that and by the time our society our civilization advances far enough to be able to build a superstructure like that will probably also have mastered interstellar space travel and at that point 500 years from now you will be sitting in your ship zipping through the void of empty space to explore a black hole one day in your ship you get tired you notice that you should arrive at your destination in about twenty thousand years so you decide to take a 20 000 year long nap and as you lie down on your cryogenic bed you very slightly bump your ship's accelerator you don't even notice after 20 000 years you awake fix yourself a cup of coffee and you notice from your gravitational sensor that something is very wrong you appear to be too close to the event horizon of your black hole you look out the window and you see an enormous profoundly black disc in space the light from the stars and galaxies behind it twisted and deformed you stare into the center of this void a cosmic eye staring back at you and it's the emptiest thing you've ever seen your jaw drops and your eyes widen and then you realize that you're not sure if you've passed the event horizon yet the point of no return you double check your gravitational sensor and it says you're not there yet you have five seconds to blast away you jump from your chair leaping toward the controls for the rockets spilling your hot coffee on your hands burning your fingers you scream and fall to the ground and by the time you get up it's too late you're passing the event horizon of a black hole you nearly stop breathing your mouth feels like sand and you close your eyes you can't believe that this could possibly be happening you open your eyes and look out the window again and everything looks about the same the disc is getting a little larger but otherwise everything is the same you feel the same nothing is different you think maybe your estimate was wrong maybe there's still time to escape you triple check your gravitational sensor and no matter which direction you point it it says you're pointing toward the center of a black hole and then you know for sure you've passed the event horizon you are inside a black hole a calm terror settles over you how did you get in this situation very slowly while you were asleep the conditions of the universe around you were changing nearly imperceptibly and then suddenly it was too late floating in your ship inside of a black hole what do you do you might start thinking of possible escapes i mean you know logically it's impossible to go back outside of a black hole but you think maybe there's something you missed you go through all the options i mean maybe all the clever scientists were wrong and there's some way to escape that hadn't been anticipated you start fantasizing that maybe if you just wait long enough or you just get lucky you will eventually pass back over the event horizon it could zoom away from the black hole back to the way things were back to the world you once knew and as you're fantasizing you look down and you see that your feet are drifting away from you and your legs are being stretched into long thin spaghetti-like strands and then suddenly your shoes are so far away that you can't see them anymore and in that split second before you reach the center you realize two things one that no one really knows what happens in the center of a black hole and two there is no going back the only way out is directly through the black hole sometimes reality becomes twisted seemingly beyond recognition and right now as the oceans burn and the global temperature rises and as literal fascists have returned to our politics and as so many of us are dead from a mismanaged pandemic you would be forgiven for thinking that we had fallen into a societal black hole in retrospect it happened so slowly almost imperceptibly while so many of us were asleep and then everything changed but just like just like in a black hole in space the only way out is through our current societal black hole is a golden opportunity to construct a better world and to think in radical new ways to do so but we'll need to dig deep very deep just like when we study a black hole in space if you want if we were able to go to a black hole in space or create one in the laboratory we would be able to study the fabric and structure of space-time to understand what creates these twisted vortices and right now we can use the current contemporary situation to collectively understand and study the fabric of society itself to understand what leads to these societal black holes how do the social structures that we have around us lead to such societal black holes and how can we upend them for example there's more than one reason why we should consider building a large collider a circular collider around the moon the first is scientific i want to know what amazing discoveries might be in this data even though i'll be long dead we'll all be long dead by the time this thing ever starts taking data because such discoveries like understanding quantum gravity could completely change our perspective on reality but there's another reason our society is addicted to repeating its mistakes and right now we seem to be on the verge of simply giving space the moon and mars to wealthy private individuals and corporations whose only interests are extraction exploitation and profit this is bad because these this extractive and exploitative mindset here on earth is leading to the destruction of humanity due to anthropogenic climate change instead of instead of allowing like encouraging a moon rush for example the moon should be protected in perpetuity against commercial exploitation and a project like this a circular collider on the moon sounds insane but it's a project that's mounted solely because our species is curious about nature centering projects like this when we explore anything not just space but anything humanity explores centering projects like this would remind us that the moon belongs to everyone the moon belongs to everyone space belongs to everyone we need to finally definitively abandon systems for example that allow lead to situations where a few dozen individuals can have as much wealth as billions of the rest of us combined we need to abandon these systems if that sounds impossible to you keep in mind gravity creates black holes and gravity is simply a law of nature but the social political and economic structures that lead to societal black holes the lead to things like extreme wealth inequality racist policing or climate emergencies these are not laws of nature they're human made which means they can be human unmade we need to finally find the courage to unmake these structures we owe it to future humans because of course it won't be you 500 years from now traveling to a black hole to explore it up close it's up to us to fix our societal inequities and it's up to us to make sure that humanity isn't crushed into oblivion so that your great great great 25 great's granddaughter can push forward into the unknown to understand better humanity's place in this vast universe.

References

Balli, F. and Balli. H.O. 2011. Sectoral equity returns in the Euro region: Is there any roomfor reducing portfolio risk? Journal of Economics and Business.

Campbell, J. Y. (1987), "Stock returns and the term structure", Journal of financial economics, Vol. 18, No. 2, pp. 373-399.

Chen, S. J., & Jordan, B. D. (1993), Some empirical tests in the arbitrage pricing theory: Macro variables vs. derived factors, Journal of Banking & Finance,Vol. 17, No. 1, pp. 65-89.

Do, G. Q., Mcaleer, M., & Sriboonchitta, S. (2009), "Effects of international gold market on stock exchange volatility: evidence from asean emerging stock markets", Economics Bulletin,Vol. 29, No. 2, pp. 599-610.

Goldsmith, R. (1969), "Financial structure and economic development". New Haven: Yale University Press.

Granger, C. W. J.. (1969). Investigating Causal Relations by Econometric Models and Cross-spectral Methods. Econometrica, 37(3), 424. .

Hans Franses, P. and Mees, H., 2010. Does news on real Chinese GDP growth impact stock markets?. Applied Financial Economics, 21(1-2), pp.61-66.

Jensen, N. M., & Schmith, S. (2005). Market Responses to Politics. Comparative Political Studies, 38(10), 1245– 1270. doi: 10.1177/0010414005279790.

Jochem, A. and Reitz, S., 2014. The impact of global factors on stock market movements in emerging market economies. Intereconomics, 49(5), pp.268-271.

Lobo, B. J. (1999). Jump risk in the U.S. stock market: Evidence using political information. Review of Financial Economics, 8(2), 149–163. doi: 10.1016/s1058-3300(00)00011-2.

Sahoo, Pravakar, and Ashwani. "COVID-19 and Indian Economy: Impact on Growth, Manufacturing, Trade and MSME Sector." Global Business Review 21, no. 5 (2020): 1159-183. doi:10.1177/0972150920945687.

Saikkonen, P., & Luukkonen, R. (1997). Testing Cointegration in Infinite Order Vector Autoregressive Processes. Journal of Econometrics, 81(1), 93–126.

Savita, & Ramesh, A. (2015). Return Volatility Around National Elections: Evidence from India. Procedia - Social and Behavioral Sciences, 189, 163–168. doi: 10.1016/j.sbspro.2015.03.210.

Seeborg M C, Jin Z, Zhu Y. The new rural-urban labor mobility in China: Causes and implications, The Journal of Socio-Economics, 2000.

Sharma, Tanya, and Tapan Kumar Shandilya. Impact of COVID-19 on Indian Economy. New Delhi: Shandiliya Publications, 2021.

Siklos, P. L. & Wohar, M. E., 2004. Estimating Taylor-Type Rules: An Unbalanced Regression?. SSRN.

Singh, D. (2010), Causal Relationship Between Macro-Economic Variables and Stock Market: A Case Study for India, Pakistan Journal of Social Sciences(PJSS),Vol. 30, No. 2, pp. 263-274.

Sprinkel, B. W. (1964), "Money and Stock Prices". Richard D. Irwin, Homewood III.

Vuchelen, J. (2003). Electoral systems and the effects of political events on the stock market: The Belgian case. Economics and Politics, 15(1), 85–102. doi: 10.1111/1468-0343.00116.

YouTube (2015) Statistics, [online] .