John Boccacino:

Hello, and welcome back to the 'Cuse Conversations Podcast. I'm John Boccacino, Senior Internal Communications Specialist at Syracuse University.

Eric Coughlin:

If you were to say, let's dive into a black hole, you could measure the amount of time or you could look at your watch as you were doing so, and you could count the seconds that go by according to you as the falling observer, and you would actually careen right through the event horizon and hit what's called the singularity at the center in a finite amount of time, meaning that there's some amount of time that would pass on your watch and poof, you would hit the singularity at the center.

And that's where nobody knows what happens, but you would be torn apart and completely obliterated throughout that whole process. So what's very confusing is that according to an outside observer, that's not actually what we would see. Instead, what we would see is you get asymptotically close, meaning you would get closer and closer to this special location known as the event horizon, but you would actually never fall through it according to an outside observer. And so as an outside observer, our time coordinate actually just continues on and on and on, and goes onto infinity, while you, as the plunging observer into the black hole, just kind of stop and get pasted onto this thing called the event horizon.

John Boccacino:

Black holes are amongst the most studied, but least understood cosmic phenomenon for astrophysicists. These objects derive their name from the fact that nothing, including light can escape the grasp of their immense gravitational field. Our guest on this week's episode of the 'Cuse Conversations podcast, he's Eric Coughlin, a physicist in the College of Arts and Sciences, and he's going to discuss shredded stars, hungry black holes, and other cool secrets of the cosmos.

Now, among the research Eric has conducted, he's examined black holes and partial tidal disruption events where black holes repeatedly tear apart or shred stars. His team's groundbreaking research offers a rare glimpse into the feeding habits of a super-massive black hole using a predictive model to forecast when a distant star will be partially consumed or spaghettified. You'll learn all about that term and other topics related to black holes. Eric, thanks for making the time to stop by and discuss this really fascinating out of this world topic.

Eric Coughlin:

Absolutely. Happy to be here.

John Boccacino:

Give our audience just a little background on yourself, your research and what drew you to Syracuse University.

Eric Coughlin:

I went to undergrad actually right down the road from where I grew up at Lehigh University, which is actually mostly known for engineering, but they do have an astrophysics BSC program, which is what I did there. I then went to CU Boulder, University of Colorado at Boulder, which is where I did my PhD from 2011 to 2016.

So I worked with Mitch Beegleman is his name, and did a lot of work related to, as you've already mentioned, tidal disruption events, these scenarios where stars can be destroyed by the tides of a supermassive black hole, essentially the gravitational field of a black hole. I then went to UC Berkeley, which is where I did my first postdoc. I worked with Elliott Quader, and then after that I was at Columbia for a year. And then I was at Princeton for one more year before I joined the faculty here at Syracuse.

And I really love Syracuse University, for one, I think just the geographic location. I just really love it here. I think it's a beautiful part of the country. I love living here. And I also think that we have just a tremendous and outstanding group of faculty who do really fascinating research, some of which is in line with my own and deals with gravitational waves, for example, which are generated by the mergers of black holes, but also topics that are completely distinct. So I think it's just a really great intellectual environment to be in.

John Boccacino:

What piqued your curiosity? What made you want to study this?

Eric Coughlin:

When I was a kid, I was always fascinated by the stars, et cetera, et cetera. But what's kind of funny is, I am really more drawn to the math than anything I would say, the math and the physics. So when I was was younger, I was 12, 13, I was like, I really like astronomy, but I don't want to just... I had the same conception, the kind of mental concept of an astronomer that most people do, which is somebody standing on a hill underneath a dark night sky looking through a telescope.

And I was like, "I don't want to just look at stuff. I want to use math and physics to be able to understand something." And somebody, either I figured this out on my own or somebody told me, they're like, "You can do that as an astronomer." And I was like, "Oh, all right, cool. That's exactly what I want to do then." And so it's kind of just been an ambition of mine for a long time.

John Boccacino:

I think a lot of us, me included as a kid, were fascinated with the term black hole. Is layman's terms, speaking to our audience here, exactly what is a black hole and how do they form?

Eric Coughlin:

The way I would describe it is that they are regions of space and time that are disconnected from the regions in which we live. And so I think the way to say it is, as an outside observer, someone who's not inside the horizon, the event horizon of a black hole, you are not able to peer beyond that thing that I've just referred to, called the event horizon. And I was looking at kind of the questions that you had. What happens to time and space near a black hole? There's this very confusing thing that happens where if you were to say, "Let's dive into a black hole," you could measure the amount of time or you could look at your watch as you were doing so, and you could count the seconds that go by according to you as the infalling observer.

And you would actually careen right through the event horizon and hit, what's called the singularity at the center in a finite amount of time, meaning that there's some amount of time that would pass on your watch and, poof, you would hit the singularity at the center.

And that's where nobody knows what happens, but you would be torn apart and completely obliterated throughout that whole process. So what's very confusing is that according to an outside observer, that's not actually what we would see. Instead, what we would see is, you get asymptotically close, meaning you would get closer and closer to this special location, known as the event horizon, but you would actually never fall through it according to an outside observer. And so in relativity, time becomes like a coordinate in a way that's analogous to how space you think of as coordinates.

So for example, if I tell you to meet me somewhere, I have to tell you the longitude and latitude on the earth. And then I also probably should tell you the floor of the building that I'm on so that we can meet there. But then I also need to tell you a time obviously.

And so the weird thing is that time as this coordinate starts to change depending on the observer and depending on where you're at in space and time. And so as an outside observer, our time coordinate actually just continues on and on and on and goes onto infinity, while you, as the plunging observer into the black hole, just kind of stop and get pasted onto this thing called the event horizon.

And so positions in space and time in relativity are known as events. And so the event horizon is kind of the farthest reach of your events as an outside observer. So it's the farthest that you can peer into the region around this thing called a black hole.

So things interior to this kind of limit known as the event horizon cannot exit. So they're forever closed off from the outside universe and vice versa. So we cannot peer into it without just diving in and then there's no coming back. So it's kind of the point of no return.

John Boccacino:

And then is it safe to assume then that the material, whatever comes in contact with the black hole, it is destroyed on the other side?

Eric Coughlin:

Yeah, I mean this is where, I mean it becomes much more suspect and you have to... So the problem is that general relativity is what you call a classical theory, which means it does not account for quantum mechanics. And so quantum mechanics deals with extremely microscopic phenomena, right? So how electrons in an atom operates and on those extremely small scales things become less, what's called deterministic. And so you think about physics. So what is physics supposed to do? Well, it's supposed to tell me, for example, if I hit a baseball at some speed and at some angle, how far is it going to go before it hits the ground?

And so classical theories are deterministic in that way. Meaning if you tell me everything about a problem, you tell me all the initial conditions, the initial velocity, the initial speed with which you hit it, the acceleration due to gravity, the air resistance, all that information, I can tell you without a doubt when and where that ball is going to land on the ground.

And that ceases to hold in the quantum mechanical world that governs microscopic phenomena. And things are just, I don't know, fundamentally limited in how well you can constrain the locations of things. And so quantum mechanics is actually really fundamentally responsible for a lot of things, like nuclear fusion for example, happens in the interiors of stars because of quantum mechanics essentially, which is really kind of fascinating, but I kind of already mentioned this, right?

So the singularity, there are two special locations kind of associated with a black hole. One is the event horizon, which we already talked about. The event horizon is what you call a coordinate singularity, which means that you can actually fall through it no problem. It's just that as an outside observer we can't see through it, but especially for really, really massive black holes, the event horizon is sufficiently large that you could actually pass through it without really noticing much, meaning you wouldn't be torn apart or anything, for very massive black holes.

But then the second kind of special place is at a singular point, which is called the singularity at the center of the black hole, which is where time and space get kind of infinitely compressed. Or another way to say it is that the curvature of space-time becomes infinite, but things also become infinitely small. And so that's where quantum mechanics should probably have a say in what is dictated ultimately by what exactly happens to you.

And unfortunately we don't actually have, what's called a quantum theory of gravity. So no, at least as of today, there's been no successful merger of quantum mechanics and general relativity because general relativity is just a complete departure from pretty much most... I would say pretty much any other physical theory we have. General relativity is completely distinct in the way that it describes how gravity operates.

John Boccacino:

You mentioned different theories and the theory of relativity, and I'm wondering if black holes have ever been used to help test, confirm or refute any of Einstein's theories.

Eric Coughlin:

I mean, to some extent the existence of black holes is automatically a test to general relativity because black holes are a natural consequence of that theory. And actually, I mean you maybe have heard of this, Einstein was really not happy about the fact that black holes were a consequence of his theory and he didn't actually believe in them.

He kind of just regarded it as a weird mathematical curiosity that wouldn't ever actually appear in nature. But now we have really direct evidence for the existence of supermassive black holes, sorry, of black holes at actually both ends of the mass spectrum.

So you asked, and this is a question I didn't address, you asked how they form. Related to that is the fact that there's kind of a spectrum of black holes in terms of the amount of mass that they have. And so on one end, on what you call the low mass end, these are black holes that have masses comparable to the mass of the sun and were generated as a byproduct of stellar evolution, the evolution of stars.

And so when very massive stars evolve, they what's called burn the fuel in their cores through nuclear reactions. And so our sun right now is burning through hydrogen in its core, so it's fusing hydrogen nuclei to form helium, and that releases a huge amount of energy actually.

But the sun does this no problem. So the sun fuses hydrogen and helium and that happens for billions of years for stars like our sun, whereas more massive stars, they actually burn through that supply of fuel relatively quickly. And so very massive stars will only live for something like millions of years instead of billions of years or tens of billions of years for low mass stars.

And so what happens is that these very massive stars, they burn through their supply of hydrogen, but what you call the inert core, so the core of helium that's left behind can't start to fuse yet because the temperature in the core is not high enough, nor is it dense enough.

And so what happens is that the core of the star actually starts to contract, which then actually liberates gravitational potential energy, which causes the envelope to expand. And the star becomes, what's called a red giant. And so you may have heard... So when the sun does this in a few billion years, it's going to expand, the envelope will expand to the point that it may actually engulf the earth, right?

It'll be so big that it'll actually grow to hundreds of times its current size, even though the core actually becomes more compact. And so once the core gets to be sufficiently dense and hot that it can start to fuse helium into carbon, the whole process kind of starts over again. And so now you have this helium burning core that is fusing helium into carbon in its center, that continues on until you have just a carbon core left, and then the same thing happens. So then you contract, you get hotter until you can start to fuse carbon into the next heavier element.

And so this kind of goes on and on and up the chain for very, very massive stars until you get to iron. Once you get to iron, fusing iron actually does not release any more energy. And so the star is kind of stuck once it gets there and it can't release any more energy, and therefore all the pressure that's being generated from that energy release just stops. And so now you have this iron core with this big envelope sitting on top of it, and the core starts to collapse under its own self-gravity. And that collapse continues until it forms, what's called a neutron star, which is an even denser version of what's called a white dwarf. And even those neutron stars can then ultimately collapse down to black holes at the end of the day.

And so that's how we think that you form, what are called these stellar mass black holes. And then way up at the other end you have what are called supermassive black holes. And so these are black holes that are sitting in the centers of galaxies. And so this is what the Event Horizon Telescope, the EHT telescope actually directly imaged. So there's this supermassive black hole in a relatively nearby galaxy called M-87. So that supermassive black hole has a mass of a few billion times the mass of the sun, and then the supermassive black hole in the nucleus or the center of our own galaxy has a mass of a few million times the mass of the sun.

And so how those massive black holes form is comparatively less well-known. And there's a couple of competing theories as to how they might form. One is called a direct collapse model, which is where you have kind of a relatively hot protogalactic gas cloud that can collapse down and kind of directly form a very, what's called heavy seed black hole. And that thing, especially if conditions are right, can actually accrete or kind of consume mass at a very, very high rate. And you can grow it very quickly up to the supermassive black holes that we're now actually seeing with the James Webb Space Telescope that are existing a hundred million years after the Big Bang.

So you have these very heavy black holes that are existing very early on in the universe, which challenges a lot of our theories as to how those things actually come to exist in the first place.

John Boccacino:

From an outsider perspective, it's always been fascinating how exactly scientists would detect black holes if they don't emit light.

Eric Coughlin:

I think prior to the Event Horizon Telescope, the answer to this is... Okay, so I think there are three ways. One is very counterintuitive and it's related to what you just said. So if everything just falls into a black hole and never comes out, how can you possibly detect it? What's very surprising is that back in the fifties, people were looking at stars and telescopes were getting more powerful, and we were able to see more distant farther out in the universe. And these objects were discovered, called Quasi-Stellar Objects or QSOs, and they were called that because if you looked at them on the sky, they looked like point sources and individual stars looked like point sources, and so people thought that these things were stars.

But when you took, what's called a spectrum, which means that you take the light and you kind of split it up into all of its constituent wavelengths, so how much light is at a given wavelength that you're seeing, these objects looked nothing like stars.

So stars like our sun, they'll have absorption lines where some light in certain bands is being preferentially absorbed, but then they kind of look like, what's called the black body, which means that they're roughly at a given temperature. Whereas these objects had extremely broad emission lines, which meant that stuff must have been moving very, very fast around this seemingly point-like object out there. And people were very confused as to what that could possibly be. And it was in the sixties then, primarily at Cambridge, so Cambridge University in the UK, where people realized that there's actually an energy source that you can tap into associated with black holes that deals with gravity.

And so the idea is that if you have... So the earth orbits around the sun, okay, that's fine, but if you have gas in the near vicinity of a black hole, it's going to do the same thing, right?

It's going to go into orbit around this object and it'll orbit at roughly a circular speed. But the thing about gas and the thing that differentiates it from just rocks is that it has pressure. So there's kind of a speed with which information communicates in a gas that's dictated by the temperature, but then it also has viscosity. So viscosity is kind of the action by which kinetic energy or bulk motion gets dissipated as heat, as thermal energy.

And if you can dissipate energy and release it as thermal energy, that can also emit a whole bunch of light. And so the idea was that there's some sort of viscous interaction, which now people think is probably related to turbulence in magnetic fields in these things called discs, so accretion discs, which you can just think of as... I always think of it cartoonishly as a dinner plate just swirling around the black hole, that causes material to sink in, so to actually sink in and get closer to the black hole.

And in doing so, it has to give up some energy, right? So it sinks deeper into, what's called the gravitational potential well of a black hole. And it releases energy as it does so, either in the form of light or in some cases mechanical energy that some material can get thrown out in the form of, what are called ultra-fast outflows or winds or black hole winds.

And this process is actually so energetic, and if it's efficient enough, meaning that if you can release this energy on a short enough timescale, black holes can actually be the most luminous objects in the universe. And so now given this understanding that we've developed, people have come up in various ways of using the properties of these accretion disks and techniques called reverberation mapping to try to understand and kind of dictate what the mass of the supermassive black hole has to be in some of these systems.

And so that's the way I would say that people have used to measure most of, or I guess infer the existence of black holes in distant parts of the universe, up until very recently. And so then two kind of new windows into the universe have been opened, one of which I've already talked about. This is the Event Horizon Telescope, which is where you use a technique called interferometry to kind of probe directly into the central regions of what have to be very nearby galaxies.

And so this only really works for either our own galactic center, so the Milky Way, or this other galaxy I was talking about, M87. But then the other one is through, what are called gravitational waves. So when two black holes get to be very, very close to one another, they actually in-spiral and they release energy in the form of what are called gravitational waves.

And a good depiction of it is that you can kind of think about it as ripples in space-time that emanate from the merging binary system, the merging binary black holes. So now to your question, have black holes been used to test any theories of Einstein? So one of them is, well, a black hole is a consequence of Einstein's theory. So in a sense, they are showing that general relativity is not completely wrong.

But then the other prediction of general relativity of Einstein's theory is that these gravitational waves should be produced. Black holes in particular should spiral into one another and release these gravitational waves simultaneously as they're doing so.

And in 2015, we finally actually directly detected these gravitational waves, these small little ripples in space-time through, what's called LIGO, so the Laser Interferometer Gravitational Wave Observatory. So it's essentially a giant interferometer, kind of think about it like mirrors, bouncing laser beams back and forth and looking at, what's called the interference pattern of the light as they re-intersect at a common point.

And essentially, if you have a gravitational wave coming by, again, you can kind of think about it cartoonishly, like the gravitational wave is changing the lengths of the arms ever so slightly, and that causes these light rays to interfere constructively and destructively, and you can actually see it then, there's this ripple that you can actually detect and see from these detectors. And so in 2015, these were directly detected, and that was just a huge, massive breakthrough for our understanding of gravitational waves and simultaneously the detection or the verification, I guess, of general relativity.

John Boccacino:

And it was a point of pride for us. So we had a large role in supporting the research, I mean, we had Duncan Brown, Stephen Ballmer, I mean, we had incredible faculty that were contributing to that discovery of gravitational waves. I want to transition a little bit to another area of your research that we've already kind of alluded to a little bit. In the partial tidal disruption events or TDEs, what do TDEs tell us then about black holes where they're coming in and they're repeatedly tearing apart or shredding stars that are nearby?

Eric Coughlin:

Usually, or there used to be two types of tidal disruption events and now I would say there's three. So first, okay, total disruption events, what the heck is that? So tides are kind of a universal feature of gravitation. So we experience tides on the earth, and the reason for this is that the moon and the sun actually exhibit comparable tidal forces on the earth because the sun is so much more massive than the moon, but it's also simultaneously so much farther away, that this tidal effect between the two is actually comparable, which is why we have spring tides and neap tides.

So when the sun and the moon are in line with one another, we have a really, really strong or really high tide and a really low tide because they're kind of acting in tandem to produce a stronger tidal field. And then when they're orthogonal, those effects cancel out and there's very little tides on those days. Those are the neap tides.

But what's happening is that there's a slightly stronger gravitational pull on one side of the earth relative to the center, and then there's a slightly weaker gravitational pull on the other side, either to the moon or the sun, pick your favorite one. And so what that does is it tends to slightly elongate. So the stuff that's over here, let's say the moon is over here, here's the center of the earth. So the stuff that's over here kind of lags away a little bit from the center of the earth.

And the stuff that's over here kind of gets dragged a little bit in the direction of the moon, so you kind of slightly elongate the earth. And then there's also, there's a directionality to gravity. And so it also simultaneously gets squeezed on this side and also on the top.

And so you get the low tides over here and the high tides over here, and you get two per day. So that effect is by no means exclusive to the earth and the moon, any two objects that have a finite size and interact gravitationally, which is everything in the universe, will experience the same sort tidal effect. So the kind of cool thing about black holes, among the many, is that they're simultaneously extremely massive, but also very, very compact. And so for example, the black hole in the center of our galaxy, I think I already mentioned this, has a mass that's on the order of a million times the mass of the sun.

The event horizon of that black hole is about the size of the sun itself. So this black hole has a million times the mass of the sun packed into the volume of about the sun.

And so what that means is that if you now have a star that's getting very, very close to this black hole, it can actually experience a really, really strong tidal force, so a really strong difference in the gravitational force across the size of the star without just plunging into the black hole and never coming back, and that tidal force can become so extreme that it can actually overcome the force of self-gravity that the star is using to hold itself together.

And so you can actually, what's called... And you said this at the beginning, you can spaghettify a star through these really extreme tidal forces that it experiences, that you can actually get a star to be tidally destroyed by a supermassive black hole, which then... So now these things become very useful. And you already said, "How can we use these things to measure the properties of black holes?"

So I mentioned at some point that you have these extremely luminous black holes in the universe called quasars. It turns out that those black holes constitute a minority of all the supermassive black holes. So there's only, at any given time in the universe, there's only a few percent of galaxies that have these very active, very actively accreting, extremely bright black holes.

The vast majority of them actually have, what are called quiescent black holes, meaning black holes that are not actively accreting gas. They're not giving off very much light. And we're back in the scenario that you asked about, which is like, how do you detect these things? Well, the answer is you can't. You can assume that they exist, they're probably there, but you can't really directly say anything else unless one of these TDEs, titled disruption events happens.

Because when you tidally destroy a star, some of that material actually comes back to the black hole at a rate that you can predict.

And again, if things kind of go right and you can, what's called circularize, and you can form an accretion disc around the black hole, that will then feed some kind of brief period of quasar-like activity and liberate a whole bunch of light from the nucleus of this galaxy that otherwise was not doing anything and you wouldn't have been able to see it.

And this is where my research comes in, is like, if you can really understand simultaneously that disruption process, so how does a star get destroyed as a function of the mass of the black hole? How does it get destroyed as a function of the properties of the star? And then you can determine how that material returns to the black hole. Also as a function of those various properties, you can start to say, well, if I observe something that we're going to call a TDE, that emits a whole bunch of energy over some timescale, then maybe I can use that timescale alongside my understanding of how these systems work, to then place constraints on the mass of the black hole and the properties of the star.

And then you mentioned partial tidal disruption events. So a partial tidal disruption event is just when the star is liberated of some fraction of its mass, but the high density core in the interior can survive the encounter. And so this is not the same actually as a repeating partial tidal disruption event, right?

Because these tidally destroyed, even the partially destroyed stars actually come from very, very far away, from very distant points in the galaxy, meaning that the star kind of comes in and even if it partially survives, the partially surviving core actually just goes right back out from where it came, and it goes back out into distant parts of the galaxy. And so you still only get one, at least in principle, you still only get one accretion event and one really bright electromagnetic outburst from a partial tidal disruption event. But then there's this very famous system called ASASSN-14ko.

So ASASSN is a survey. And so the idea with a survey is that you have a telescope or an array of telescopes that kind of just pans around the night sky and takes exposures of patches of the sky. So you take your telescope, you stare at some square degree patch of the sky for some amount of time, and then you move on and you look at different other patches of the sky and you keep looking at other patches.

And then after some amount of time, after some cadence, you go back to that first patch that you started at, and you do the same thing. You just stare at it for the same amount of time, and then you take a difference of the two images and you say, "Does anything change?" Was there any new source of light in that patch of the sky? So it's an extremely simple but extremely efficient method for detecting, what are called transients.

So these things, like supernovae, right? These giant explosions that release energy on human timescales, and TDE's are just like that, right? TDE's are predicted, and this is part of where my research comes in, are predicted to rise and fade in brightness over time scales that are comparable to weeks, which is obviously very amenable to human beings. And so now we're starting to see many of these systems, and one of them that I already mentioned, this ASASSN-14ko event, the 14 stands for 2014. So this thing was first discovered back in 2014. This event or this system has now shown repeated outbursts like clockwork.

It's like 20 or 30 times that this thing has outbursted. So every 115 days, this thing shows an outburst that lasts for some amount of time. And the question is, what the heck is doing this? What is powering this weird clockwork-like system to do this? And so the hypothesis is that you have, what's called a repeating partial tidal disruption event. So somehow you get a star onto a bound orbit around a black hole. So bound just meaning that it's going to come back on a timescale that's comparable to 115 days.

Every time the star gets to its point of closest approach with the black hole, it liberates some amount of mass. And that mass then makes its way back to the black hole and fuels one of these accretion episodes and liberates a whole bunch of energy.

John Boccacino:

When you're studying these cosmic phenomenon from 860 million years ago, and you consider just how small our physical impact is on the history of the universe, what is that studying of these cosmic phenomena, what does that teach us about our place in the universe?

Eric Coughlin:

I think it was like Carl Sagan has this very famous statement where human beings are stardust. The idea is that the universe, when it was born, when the Big Bang happened, there was mostly just hydrogen and helium. But you know that on the earth, we don't have just hydrogen and helium, we have all the carbon that makes us up. So all that carbon actually came from stars, and through then subsequent star formation processes, all that material gets amalgamated into various places. And one of those places is actually us. And so we are actually just recycled star stellar material in some way, which is really... I mean, that's a really profound way of thinking about some of these processes and how they affect us.

So I think for tidal disruption events, what it really shows to me is how incredibly powerful these places are in the universe because it's easy to, especially in astronomy, the numbers that you deal with are so big that it's very easy to just get kind of used to the enormity of all the things that you talk about.

So you kind of like, it's easy to get lost in how huge the universe is. And I think what tidal disruption events are showing us is that there's places in the universe where you can take an entire freaking star, seven times 10 to the 10 centimeters, that big, so much stuff packed into it and just rip the entire thing apart. Put yourself in the frame of the star. The star is careening toward the center of the galaxy, but it actually has no idea because the star is just freely falling in the gravitational field for the most part.

And that's one of the weird things about gravity, and it's one of the amazing insights that Einstein had, which is that you actually don't feel your own weight. So when you're on a roller coaster, for example, and you go over the top and you start to come down and you feel butterflies in your stomach, that's the lack of the weight of your organs that you don't feel.

So if you're just sitting alone in an empty space, you could be in a gravitational field, but actually, if you're not fighting it, if you're not doing anything against it and you're just going with the flow, you actually don't know that you're in a gravitational field. The only way that you know is actually through tidal forces, is through the difference in the gravitational field, that is actually true gravity. And so for the star, if you think about it, the star is careening toward the center of the galaxy, towards something that it can't even see because it's a black hole.

And then all of a sudden it starts to feel like this light stretching force, and by that point it's too late and the whole thing just gets shredded, and the whole thing happens on the timescale of an hour. So can you imagine taking an entire star and just [inaudible 00:34:00] part in an hour? It's just a crazy absurd thing to think about. And so I think that's one of the really cool aspects of this.

John Boccacino:

What do you try to impart upon the students that you teach about what they might be able to contribute or pursue when it comes to this line of research?

Eric Coughlin:

I actually really like, I enjoy working with not just graduate students, but also undergraduate students at SU. And I've been really lucky from the standpoint that I've had some phenomenal undergraduate students that I've been able to work with. So Matt Cufari, for example, was actually the first SU student to win, what's called the LeRoy Apker Award, which is the highest honor that the American Physical Society bestows on an undergraduate researcher, an undergraduate student.

So Matt Cufari graduated a couple years ago. He is now a grad student at MIT who did some really fantastic research with me. And then Julia Fancher is another undergraduate student who's currently at SU. She's a senior, so she'll be graduating and applying to grad school this year, has also done some really phenomenal work with me. She's won the Goldwater Scholarship and also the Astronaut Scholarship. Research, it's really just, it's like scientific exploration.

And part of that, actually, I would say most of it is just getting things wrong. I mean, science in practice is very ugly. It's full of false starts and dead ends, and just trying to get something to work. Working with undergraduate students, I try to have an idea of a project that I'm pretty sure is going to lead somewhere, and I know is going to have tangible results because I want students to be able to see that.

And then with graduate students too, I have the same mentality, I guess, or methodology that at the beginning I want you to be able to develop not just necessarily the intuition for a problem or the way that the physical evolution of some system works, but also the methodology itself. I think students can make an impact while they're undergraduates and certainly while they're graduate students. And I also think, for me, I think it's really important to sort of show them, not just here's how this problem works, but I also want you to kind of go off on your own and try to explore and get stuff wrong because it's really just an essential part of science.

John Boccacino:

I want to thank our guest on the podcast, he's Eric Coughlin, a physicist in the College of Arts and Sciences. Eric, keep up the great work, and thanks so much for making the time today.

Eric Coughlin:

Absolutely, John, it's been really fun. It's great talking to you.

John Boccacino:

Thanks for checking out the latest installment of the 'Cuse Conversations Podcast. My name is John Boccacino, signing off for the 'Cuse Conversations Podcast.