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HOST: When we think of black holes, we think of a dark and terrifying, unknown that distorts everything. A vacuum so powerful that we're still learning new information about it, but have we ever considered black holes to be polite? To one astronomer black holes don't just have excellent manners, they're also incredibly awesome.

Welcome to The Conversation Piece. This is McGill University associate professor of physics, Daryl Haggard.

DARYL HAGGARD:
Hello, I am Daryl Haggard and I am here to tell you about black holes. So I really enjoy some call and response, especially since now we're here coming toward the second to last talk. , so I'm going to ask you questions, a few questions over the course of my talk and I would like you to respond if at all possible. So my first question to you is what planet are we on?

AUDIENCE: Earth!

DARYL HAGGARD: Awesome. Okay. So we're, we're off to a very good start. At the end of this presentation, what I would like you all to say to me is if I tell you that black holes are truly awesome and that they really don't suck, I would like you to be able to respond to me that black holes don't suck and really believe what you're saying. So that's my objective here today.

I want you to know that black holes really, they are not cosmic vacuum cleaners. They don't go rogue around the galaxy and gobble things up. That's not what they're about, and that's not what they're up to. I would like you to think of them as very massive objects with very excellent manners.

So black holes are truly and very, very well governed by our theory of general relativity. So far, despite many tests that we have put these two, we have never seen deviations away from general relativity, and they seem to really be guided by this kind of amazing theory that governs a lot of what we think is going on with gravity. So you've heard a little bit about gravity from other speakers today. , and I would like you to think now about the mass involved in black holes to remember that they are indeed truly very, very small, but they are still spectacular. , and so I'd like you to start thinking a little bit about the awesomeness of black holes in the context of this really amazing image that I think might appear, Oh, that's up to me.

Here's the black hole. Have you all seen this picture before. It's kind of an awesome thing to be an astronomer and have a lot of people say yes, when you show them a picture of a black hole, that's a new thing that we can actually show you an image and be able to tell you a little bit about what's going on with this incredible image of a black hole. So they are really awesome creatures. This is the very first picture we've ever been able to of the photons swirling around, very close to the event horizon of a supermassive black hole. So I'm going to use this image as my prop for a minute, to help you understand a little bit, my favourite definition of what a black hole is. So I like this very toy model. There's a lot more complications to it than this, but think of a baseball and what happens when I, Darryl Haggard throw a baseball, be honest with me.

I see some people doing this. That's literally what would happen. It would just fall down, right? So, the baseball, it falls back down to the surface of the earth. I'm not that strong. I'm actually, I'm, I've got a pretty terrible throwing arm. So this baseball falls back down because of the gravity of our planet. And so it's experiencing our gravitational pull, the planet's gravitational pull, but it turns out that if I could accelerate, just put a little rocket on the back of that baseball and accelerate it up to 11 kilometres per second, or just a little bit more. I can actually get that baseball out into orbit, or even completely out into outer space off the surface of our planet. So 11 kilometres per second, if that's not your, you know, ball of wax, maybe you prefer Queens units. That's something like 25,000 miles per hour, right?

Our cars don't go that fast, but sometimes our rocket ships do. So. The thing about a black hole is that that velocity, that escape velocity, the velocity, you would need to give a particle for it to escape off. The surface of that body is faster than the speed of light. So, light is trapped inside the black hole and light is the fastest velocity. Those photons are travelling at the fastest velocity. We know of. It's a fundamental constant, so lights stuck in there and that's why we call them black holes. But this image is a picture of all of this stuff, just outside the black hole, just outside the event, horizon the black hole. These are the photons and the hot gas and the hot material swirling just outside the horizon of this black hole. So let me tell you just a little bit more about this particular black hole.
, this one we like to use relative units in astronomy. So we often measure things in terms of other things, because otherwise the numbers are just a little bit hard to hold in your mind. So this black hole is 60 65, whatever 6.5 billion times, the mass of our own sun. So that's a lot of mass, but that mass is packed into a really small space. So I'm borrowing this cartoon from XKCD, which some of you might recognise. That's a little picture of our son and Pluto's orbit and the Voyager satellite, which is the farthest thing we've ever managed to throw out into space. And that scale is super imposed on this super massive black hole. So 6.5 billion times, the mass of our sun crammed into a space, roughly the size of

our solar system. That's what makes it a black hole. If that still doesn't quite kind of match your intuition.

Let me give you another example. Here's a really small nuber, relatively speaking. This is three millionth of the mass of our sun. Anybody know of that might be, I made you say it: before Earth. Okay. That's exactly right. So our earth has about three millions, the mass of our sun, but the earth could be a black hole too. If you could just smash everything, your mom, your dad, some of the moms and dads in the audience tonight, all the trees, all the oceans, all the buildings, all the continents into something, the size of a sugar cube, that would also be a black hole. It's not that our earth, all of a sudden sucked everything in. It's just that you compacted all of the mass down into a very small vole. And that's what gives you a very high escape velocity. So I'm just going to let us now take a little journey to wrap up my time since I'm running out, this is a beautiful image made, , to help you walk you into the universe where this amazing supermassive black hole resides at the heart of the so-called Virgo cluster of galaxies.

So we're zooming toward the constellation Virgo in the night sky. And there's a massive cluster of galaxies is the nearest structure of galaxies to our own Milky way galaxy and in the inside of this incredible cluster of galaxies, there's a particularly massive galaxy right in the centre called mad seven. And you can already see here that through other pictures, we can see a jet zooming out of the black hole. And as we zoom in a little bit further, we can actually see that jet structure continue all the way down toward the very, very heart of this galaxy. This jet is kind of pointed toward our line of sight, , which is a little hard to make out in these images, but this is all real data zooming in closer and closer and closer until we reach the event horizon. So not only does this black hole not suck, it is throwing material and energy out into the universe at scales that are enormous compared to the size of the galaxy that hosts the black hole.
Go, let me just show you one last little video here, which is actually going to show you the photons and orbit around the black hole. Just to further make the point that not only does it not suck in mass and dust and people and astronauts, the black hole doesn't even suck in the photons. These are simulated paths now of photons in orbit around a supermassive black hole, like the one that we saw in med seven. And you'll see that they're bending just like the light in through your glasses gets bent to focus on your retina. The black hole does bend the photons just a little bit due to gravitational lensing and make this beautiful ring image that we see. So it's not sucking the photons in, but it does redirect them a little bit to give us as really amazing kind of structure that we've now viewed. All right. So that's all she wrote. So when I tell you that, I think black holes are awesome. You are now going to tell them?

AUDIENCE: Black holes don't suck!

DARYL HAGGARD: Thank you.

HOST: Daryl Haggard is a Canadian research chair in multi messenger, astrophysics and associate professor of physics at McGill University. And she spoke at CIFAR presents The Walrus Talks Exploration in March, 2020. And she's just one of over 800 fantastic Canadians who have wheeled, webcammed, and walked onto a stage at The Walrus Talks.

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