WESTERN SCIENCE SPEAKS PODCAST
SEASON 3, EPISODE 1

EPISODE TITLE

The draw of the galactic abyss: What you may not have known about black holes.

PODCAST SUMMARY

Few would argue the magnetism of space and its mysterious nature. An endless puzzle looming over us, begging to be solved. At the heart of our extra-terrestrial conundrum are black holes; an irresistible juggernaut, seemingly capable of so much - yet barely understood. Western Science Speaks hosts Western's resident black hole expert, Dr. Sarah Gallagher from the Department of Physics and Astronomy, for a discussion about what we truly know about black holes, some of the common misconceptions about them, and a few of the most interesting theories Dr. Gallagher has came across.

INTERVIEW

You're listening to the Western science speaks podcast. Presented by Henry Standage.

Henry Standage 0:13

Of all the wonderful fascinating enigmas that lie in the space above us, few would argue that there's a more compelling unknown than black holes. Are they the thread that binds separate universes? Conversely, are they just simply a huge lurking vacuum? Or are they any and everything in between? The truth is we don't know. Sara Gallagher from the Department of Physics and Astronomy at Western University studies how black holes grow and form. We sat down to discuss her research and the greater mystery surrounding black holes.

Henry Standage 0:52

How much of what we know about black holes is based on direct evidence and how much of our knowledge is based on indirect evidence?

Sarah Gallagher 1:00

So, it depends to some extent, all evidence that we have in astronomy is indirect, because the way we get information about the world is from the light that comes to us. So, something happens out in the universe and the light travels through space and time to our telescopes and we observe it, and we have to interpret it. And so in some sense, all we know about black holes is indirect. But even more so because black holes themselves don't actually give off any light. So, we don't have any light that comes directly from the black hole, we only see the effect of the black hole on its environment. There's one way in which that happens, where if you have gas that's falling into a black hole, so it's swirling around kind of like a whirlpool, and it loses energy. Then as it loses energy, it gives off light, and then it can fall into the black hole. So, we see the light from that whirlpool around it that we call the accretion disk, and that's how we learn about the black hole. We can also learn about black holes, if they have a companion, another star that's orbiting around them. And the first black hole that we had really strong evidence for was a black hole that had a companion star. And you can watch the motion of that companion star. And you know, because of its motion, that there's something else there that we can't see that's causing it to wobble. And, we can measure precisely the mass of that object that's causing it to wobble and that's how we determine the mass of the first black hole.

Henry Standage 2:26

So, it's a pretty spectacular theory.

Sarah Gallagher 2:30

Yes, it is spectacular. So, there were there was a lot of circumstantial evidence that there were black holes out there. There was actually, quite a long time ago, there was a physicist named Laplace, who basically was studying gravity and realized that if you take gravity to its extreme, you should wind up with something that is so dense that there's no force that is able to hold it up against its own gravity. And it should crush down into a black hole. Another way of sort of defining a black hole is that you think of it as an object where in order to escape from it, in order to have a speed that's fast enough to escape from the black hole, it has to be as fast or faster than the speed of light. And that's the formal definition of a black hole. And that surface where that's the case is called the event horizon. And the event horizon is the surface within which the black holes exist. And we cannot know anything about what happens past that event horizon. On that surface of the event horizon and past it, the gravity of the black hole will affect the objects around it and the material around it. But once you cross that event horizon, you can't know anything else. It's a one-way street. We just don't know what happens after that happens.

Henry Standage 3:55
Now I'm interested to know, are there different types of black hole I know they differ in size. But are there particular differences between one black hole to another?

Sarah Gallagher 4:04
So black holes are actually remarkably simple objects. So, you can completely describe them with three numbers, the mass of the black hole, the spin of the black hole, and the charge of the black hole. And we grossly characterise black holes in terms of whether their stellar mass black holes, about the same mass as our Sun or up to say 100 times the mass of our Sun, or supermassive black holes, which are, say a million to a billion times the mass of our Sun. There's nothing really fundamentally different about them, except that we find them in different locations. So, the supermassive black holes are always in the centres of galaxies. And stellar mass black holes are found throughout galaxies. So, there are many, many stellar mass black holes that we know about in our galaxy. But all it is, is the spin and the mass and that's it. So, they're extremely simple objects.

Henry Standage 4:54
Sounds like the plight of humanity will come from a stellar black hole.

Sarah Gallagher 5:00
We actually don't need to worry about black holes in that sense, because if our sun, for example, turned into a black hole tomorrow, it would not affect the orbit of the Earth. So, Earth would simply keep on orbiting the same old orbit, it would, of course, be dark. But it's only objects that are quite close to a black hole that know the difference between a black hole or a more normal object like a star. It's only when you're quite close that it really matters. So black holes are actually quite rare in the universe. The chance that the Sun will encounter a black hole as it orbits the galaxy is extremely, extremely, extremely small. So, we don't have to worry about being swallowed by the giant, supermassive black hole in the centre of our galaxy.

Henry Standage 5:45
Let's shift to your work. You look at how they grow. So, can you give me an explanation of how a black hole grows?

Sarah Gallagher 5:51
Sure. So, when you have a black hole that is in the centre of the galaxy, if there is material that is close to that black hole, gas - which is the fuel for star formation, so all galaxies are filled with gas. That gas as it gets close to the black hole, needs to lose energy in order to fall into the black hole. And so, what happens is it will settle into a disk and the material will orbit around the black hole. And to lose energy it will get hot with this sort of friction in the disk of orbiting gas. So, it will get very hot and it'll give off light. And then the material can fall into smaller, closer and closer to the black hole and eventually fall into it. So that system is called a quasar. That's what you call it when a supermassive black hole is growing. quasars are basically machines that convert gravitational energy to light, and they do it incredibly efficiently. They do it much more efficiently than the sun converts mass into energy through fusion. So, they're among the most efficient processes we know in the universe for making energy, for generating energy. And this tiny black hole, it's tiny compared to a galaxy. So, a black hole system is a few light years across, and it's in a galaxy which is 100,000 light years across. But that tiny system of the quasar with its

accretion disk and the gas falling into the black hole can outshine the trillions of stars in the galaxy by 1000 times. So, they are very, very efficient engines for converting gravitational energy to light.

Henry Standage 7:37
That is nowhere near an intimidating enough name for the process of black hole eating, but what does that understanding of how they grow and survive unlock for us?

Sarah Gallagher 7:48
There are a couple things that are really, really interesting about black holes. One is that if you really want to understand how physics works on all different scales, you have to really probe the extreme ends of it. And it doesn't get much more extreme than a supermassive black hole. That's where our understanding of gravity, for example, really gets tested and pushed because it's such an extreme environment. And it's not the sort of environment that you can ever test in the lab. So, you have to go out and look in the universe in order to understand that there are also processes that have to do with black holes that are related to how galaxies evolve. So, we live in a galaxy, the Milky Way, and our galaxy has been changing over the history of the universe. And if we want to understand how our galaxy changed over the history of the universe, a big part of that is understanding how the supermassive black hole is in the centre of its group. It's just part of the galaxy. So, part of understanding galaxies is understanding that piece. And the other way that it's linked to how galaxies change is that as that black hole is growing, and it's giving off tremendous amounts of energy, that energy can affect the galaxy itself. The light that it sends out, it can send out x rays and gamma rays and lots of really intense radiation. And that light itself can actually blow really, really fast winds. Because the light, every photon of light, every particle of light, packs a little bit of a punch. And so, that light from that accretion disk, which is blowing so brightly, can drive really fast winds up to 10s of thousands of kilometres per second into the galaxy. And those really fast winds can impact what the galaxy does later, it might cause stars to form because it causes giant clouds of gas to compress and form stars. Or it might be so energetic that it just clears all of the gas out of the galaxy, which will prevent that galaxy from ever forming stars again. So, both of those are quite important for the history of the universe. And that's how that tiny Black Hole in the centre of the galaxy can impact a much bigger system that it lives in.

Henry Standage 10:04
Wow. So that winds not used for bringing stuff into the black hole it's actually used for clearing the path, right?

Sarah Gallagher 10:11
Well, the wind actually serves more than one function in the system, because one thing that the gas has to do before it can fall into the black hole, is it has to lose energy. And in particular, it has to lose its rotational energy. So, the material is swirling around, and it has to lose that rotational energy in order to fall into the black hole. And those winds can actually carry that rotational energy away, which allows the stuff that's in the accretion disk to fall into the black hole. So, we think they're quite important actually, for growing them as well as for impacting the galaxy that they live in.

Henry Standage 10:47
And this is what you specifically look at more than anything. How do you look at this here at Western?

Sarah Gallagher 10:55
I use telescopes from around the world and from the ground and from space. So when you have light from that accretion disk, which I said is so luminous that it can outshine thousands by thousands times the stars in the galaxy, that light, there is a signature for everything that is imprinted on the light, leaves a mark. And so when you look at the light and you take it and you, you look at it as a spectrum where you take the light and you spread it out, so you can look at all the light wavelengths separately - you'll see specific marks for specific atoms. And what you can do is you can look at the signature in the spectrum and actually learn a tremendous amount about the material in the wind. You can learn how ionised it is, how much stuff is in it, how fast it's moving. And if you have a really beautiful spectrum, you can learn where it is in relation to the black hole. So, with all that information together, we can learn quite a lot about the winds. What we want to know is how much material is in them. What

their shape is, those are the sorts of things we want to know. But we can use the spectrum to try to figure all of that out.

Henry Standage 12:06
Right. My last question is, there seems to be some pretty radical theories or misconceptions about black holes out there, like the climax in any sci-fi space movie is when they get close to a black hole and its people playing with that idea of the great unknown. What aspects of black holes do you hear that are purely based on speculation?

Sarah Gallagher 12:27
So, one idea people have is that black holes sort of suck things in. And that's not quite exactly what happens. As I mentioned before, if the Sun turned into a black hole tomorrow, the Earth's orbit would not be affected. So, the effect of the extreme environment on the black hole only happens really close to the black hole. There is part of it, though, that is wonderful for speculation because once material crosses the event horizon, we have no information about what happens to it, we just don't know. So, there's an idea that a black hole could be a wormhole, which could be a path to another part of the universe, that could actually be true. So, the theory of general relativity allows that to be true. We just don't know if we live in that kind of a universe. So, in that sense, speculate away. I mean, we have no information about something once it passes the event horizon. Black holes could be filled with leprechauns and rainbows, we just don't know. All we know is the mass and the spin. So, when something passes that event horizon, we have no information about what happens afterwards. There are theories actually, that every black hole creates a new universe. And so, the most likely universe we live in is one with lots and lots of black holes. Who knows? I don't know. So that's one thing that I think is really fantastic about them, is there in one sense so simple, but also very, very mysterious and there's something that's ultimately unknowable about them. Which I'm okay with. I mean, as a scientist, I don't need to know everything. I know how they grow. And I want to know how they affect what's happening around them. But there is this central part of them that's just unknowable, which I think is pretty extraordinary.

Henry Standage 14:21
I like that the science right now is so based on moving forward and looking, what can we do with this, progress, advance and more. But I actually like how black holes covers that, there unknowable, there's so much to learn. But then there's also the question of how did they get here, there are questions where we need to move backwards, which I think makes it really just a really cool topic.

Sarah Gallagher 14:42
For sure. So, we're not really sure how you get supermassive black holes in the centres of galaxies. So, we know how you get a stellar mass black hole. If you have a really massive star at the end of its life, it will explode as a supernova and the cinder that it leaves afterwards can be a black hole. So that's how the universe can make black holes that are, you know, several times the mass of our Sun. But to make the really big ones, we don't know how you make those. So, the best idea about how that happens is that in a very, very early universe, the very first stars were different than the stars that are made today, because they were only made from hydrogen and helium, the remnants after the Big Bang. So those first generation of stars were much, much more massive than the stars that are made today. And so, they're centres that they leave after their life is done, and they've exploded and a supernova, are going to be quite large black holes, maybe 100 times the mass of the Sun, or several hundred times the mass of the sun. To see black holes from the very early universe, the very first generation of stars. Over time, they will merge together, and they will fall to the centres of galaxies, because they're very dense and very massive. So, they'll tend, to sink towards the centre of gravity and then they can grow over time as quasars. So that's how we think that we get the black holes in the centre of galaxies.

Henry Standage 16:12
Well, some heavy duty stuff, absolutely the largest scale podcast we've done.

Henry Standage 16:19
It's impossible to comprehend something that may casually be 100 million times the size of our Sun. But with research like Sarah's we can come to understand black holes in the same grounded way we've come to understand

everything we can feel and touch on Earth as living, growing things. I'm Henry Standage, signing out. Thanks for listening.