

Andrew S.: You're tuned in to 90.7FM, KALX Berkeley. I'm Andrew Saintsing and this is The graduates, the interview talk show or we speak to UC Berkeley graduate students about their work here on campus and around the world. Today I am joined by Fatima Abdurrahman of the Department of Astronomy. Welcome to the show, Fatima.

Fatima A.: Thanks for having me.

Andrew S.: It's so great to have you here. So I hear you study black holes.

Fatima A.: I do, among a few other things. But yeah, that's kind of what occupies most of my time these days.

Andrew S.: How does one study black holes?

Fatima A.: That's a very good question. The question that might come before it is, why is a black hole hard to study?

Andrew S.: Why is a black hole hard to study?

Fatima A.: Not to do your job for you-

Andrew S.: It's cool. Jump in whenever you want.

Fatima A.: Right. So the thing about black holes, in case people aren't aware, the reason we call them black is that we cannot see them. Because of the very, very strong gravitational influence they have on the area around them, light cannot escape from a black hole once it gets too close in, so they are an inherently invisible. For something to be a black hole means it is undetectable in itself. That's why black holes are hard to study, so the whole point of what I try to do is kind of just trying to find them first. I look for black holes and then try to count them, basically.

Andrew S.: How do you look for them?

Fatima A.: There many different ways that people have kind of overcome this difficulty of black holes being invisible and floating off in space very far away from us, and have still managed to find some. The ways people get around this is basically by looking at the effects black holes have on objects around them, or maybe not even necessarily around them, but objects between you and them, perhaps. Just like I always give the example of you can't see the wind, but you can see trees kind of leaning over. You can see hair blowing, you can see leaves blowing in the wind, whatever. We look for the effects, and the particular effect I look for in my research in order to determine whether or not there are black holes around, is something called gravitational lensing.

If you were to imagine you're looking out at the sky and there's a some star that you're looking at, if a big glass lens were to pass between you and the star, it would magnify the light from the star, right? Just kind of like a magnifying lens would, and you would see some distortion just like you see distortion anytime you look through glass. Well, turns out that if you have enough mass and enough gravity, anything can distort light the way a lens does. If instead you replace that lens passing between you and a star with a black hole passing between you and a star, the black hole and it's super-strong gravitational influence can also work to warp spacetime in such a way that the light, coming from a background source, whether it's a star or whatever, is distorted. And so I look for that distortion and try to understand the signal we see in that distortion in order to infer the presence and then properties of a black hole.

Andrew S.: Okay, so the mass of an object actually bends light?

Fatima A.: Yeah.

Andrew S.: But it has to be super-massive.

Fatima A.: I mean, theoretically anything does it, anything with mass-

Andrew S.: You and I could bend light?

Fatima A.: Sure, but just like by the tiniest, tiniest, unmeasurable amounts.

Andrew S.: Right. So you would need it an impossibly sensitive sensor to see light bent around a human.

Fatima A.: Exactly. So anything with mass technically is distorting space-time to some degree, but a black hole is a thing with enough mass concentrated in a small enough volume that it produces these effects on scales. We could see it. And in fact, other objects also produce the same effect. People can use this same technique to find planets orbiting other stars. It's pretty routinely used to do that, in fact. And people have detected other objects like this. It just kind of lends itself really nicely to black holes because it is a technique that doesn't depend on seeing the object you care about. Right?

Andrew S.: Right.

Fatima A.: So you could use it for anything. It's very useful in black holes, but also other things.

Andrew S.: Right. So it's easier to see things that are more massive?

Fatima A.: All other things being equal, yes.

Andrew S.: Oh, so what else is there to worry about?

Fatima A.: Everything you can think of, basically. How far away is the black hole? How far away is the thing that it's distorting? Does it pass by directly in front, or is it a little bit offset? How fast is everything in the equation moving? Like is it the thing in the background stationary or is it moving, is it moving the opposite direction of the thing passing in front? There's quickly a lot of ways you can complicate the situation, but all other things being equal, the thing with more mass would create a bigger distortion, act as a stronger lens.

Andrew S.: Okay. So based on the distortion, you can tell whether or not you're looking at a black hole usually? Is that kind of how it works?

Fatima A.: The distortion tells you that something is there, and then all my work is basically trying to determine what the something is.

Andrew S.: How would you even do that?

Fatima A.: That's a great question.

Andrew S.: Is that what you're doing right now [crosstalk]-

Andrew S.: This is literally what I've been sitting at my desk doing all day. It's basically a game of eliminating everything else, which kind of seems like an impossible task because there's a lot of things in the universe. If we're looking for something invisible, then we can only fairly say it's that thing if it's nothing else, right?

Andrew S.: Right.

Fatima A.: Even seeing this distortion, we're never going to be able to see it. We're never going to be able to check what the thing ... I mean, for now, what the thing is so we just have to say, "Is it a star of this variety?" "No, it's not that." "Is it a planet?" "No, it's not that." "Is it a neutron star?" "No, it's not that," And we have to come up with different, clever ways to eliminate any other possibility of a thing very meticulously and with lots of data.

Andrew S.: Wait, the thing that's come out recently, right, is the gravity waves?

Fatima A.: Right.

Andrew S.: Is that starting to help people to quote unquote see black holes?

Fatima A.: Yes, so gravitational waves have been detected by LIGO are kind of what you get when you have not just a massive object existing, but a massive object accelerating. So if you

have something very, very massive, like a black hole and it accelerates, it emits gravitational waves and then we detect them here on earth. One really easy way to have things accelerating is things going around in orbits because circular motion is acceleration. Physics 101. And then if you have two black holes orbiting each other, this is a situation in which you would ideally measure gravitational waves because you have two very, very, very massive objects going around in circles, which means they're accelerating and, as they would fall into each other, they would accelerate even faster.

By looking for gravitational waves, LIGO has been able to detect black holes. However, because of the nature of this detection method, they can only find black holes that are in binaries. It's always two black holes orbiting each other, or one black hole and one neutron star, or potentially two neutron stars, but you have to have a pair.

Andrew S.: What's a neutron star?

Fatima A.: A neutron star is ... A good way of summing up a lot of things in space is you have stars and then when a star dies, different things could happen to it depending on how big it is. The biggest stars will become black holes when they die. The second biggest class of stars will become neutron stars, and that's basically just another kind of end result or a stellar corpse, as we say in astronomy, that is a big ball of neutrons, simply put. But then you have weird effects on them like star quakes, and super-fluid and super-conductive interiors and all these crazy exotic things.

Andrew S.: So it's a big ball of neutrons, neutrons being just one of the particles in atoms. So you got rid of all its protons, is that what you're saying?

Fatima A.: Exactly. No protons, no electrons. It's just the neutral part of atoms, which is a weird thing to imagine, but we think it exists. I mean it's, quote unquote, been known to exist for a very long time, the way we know anything in astronomy to exist. I like putting conditions on that a little bit, but ...

Andrew S.: Sorry, I got off topic.

Fatima A.: So many tangents.

Andrew S.: We were talking about why gravitational waves. First off I brought up gravitational waves, but I'm not fully sure I understand what a gravitational wave is, so could you just describe that too?

Fatima A.: Goodness, I'll try. I'll try. Let's see. What is the gravitational wave? What's the best way to put this? When you drop a stone into a pond, you can see the ripples kind of move outwards from where that stone fell in, right? And if you think of what the ripples actually are, it's like almost a ring of density emanating outwards, right?

Andrew S.: Right.

Fatima A.: Like there's a little bit over the water that's all bunched together, and that bunch propagates through the water and moves out from the center. And then you have continuous bands of higher density, right?

Andrew S.: Right.

Fatima A.: So imagine that except instead of water being the thing that you have rings of density emanating outward from the center, it's space itself. So a gravitational wave is a wave that propagates through space itself. Sound waves move through air, water waves move through water, gravitational waves move through space itself, which is a very out there idea to imagine. But it's literally like the space we exist in contracting and expanding in these like ripples outwards from wherever two black holes are smashing into each other somewhere in the galaxy.

Andrew S.: We ourselves and everything around us is expanding and contracting.

Fatima A.: Exactly. In tiny, tiny minute ways, and the reason we can't tell, besides the fact that it's very tiny, is because anything we would use as a reference point against which to measure these contractions and expansions basically you get from wave, is also subject to that, right? If this room that we're in just shrunk by an inch, the ruler we would want to use to measure the change in the size of the room also shrunk by some scale appropriate amount. So these gravitational waves are moving through the universe, but almost anything we could use to measure them are kind of useless.

Andrew S.: How do you even handle that?

Fatima A.: That's a great question. Definitely wasn't setting you up for that one. The answer's lasers. So the one thing that is exempt from this brutal contraction and expansion of gravitational waves that we're all subject to is light. Light has this remarkable quality that no matter ... Well, I shouldn't make any really all-encompassing statements. So light will still travel the same distance in whatever amount of time, even if there are gravitational waves happening in the space it's in basically.

If you would imagine the detectors they've built for gravitational waves are these really, really long tunnels. I don't know if they're like a mile, or several miles, or like less than a mile, but roughly that scale. Really, really, really big structures. Right? And you shoot a laser down these tunnels and you have two of them that are perpendicular to each other, and there are mirrors or whatever at the other side sending them back, or maybe it's just a sensor detecting when the laser light arrives there, and you know how long the tunnel is and you know how fast light travels.

So if you send your little laser pulse and it gets to the end of that tunnel a mile long in a time that is different from what you expect, that means that the space that the laser was traveling through must have changed.

Andrew S.: Dang.

Fatima A.: Right?

Andrew S.: That's insane.

Fatima A.: It's a lot. It's a lot. Hopefully I'm making this clear, at least a little bit, but that's basically it. It's you know how fast light is moving, so if you set light on a certain path and it deviates from that path you expect it to be on, that must be because spacetime is all warped. Right?

Andrew S.: Wow, that is so crazy.

Fatima A.: It's really ... it's pretty crazy.

Andrew S.: Just to remind that you're tuned into The graduates. I'm speaking today with Fatima Abdurrahman of the Department of Astronomy.

Okay. Honest question, when you think about things on astronomy, do they actually make conceptual sense to you at a certain level? Like where-

Fatima A.: Sometimes.

Andrew S.: So you just kind of have to be like, "This is the physics of it and that's how I'm going to understand it," or are there things you just can't comprehend on a certain level?

Fatima A.: It really depends. I will admit that I'm very often not confident about much of the things I say, many of the things I say. Because, I mean it's just crazy to me when people say stuff about something that happened 13 billion years ago, however many light years away when the universe was a tiny spec or ... I mean, it's not like we don't use a lot of data and rigorous methods to support everything we do in astronomy. But I never feel confident being like, "Yes, there is a neutron star at exactly this position in the galaxy doing exactly that." I mean, there's so many steps of logic we needed to take to get there, so I always kind of approach everything with a little bit of hesitation. But then even beyond that, I mean there are plenty of things, like when somebody says, "And then spacetime is warped," like we live in a 3D world and experience time, it's physically impossible for me to conceptualize what that even means.

You can kind of try to understand things like that through analogy, by describing two dimensions and then projecting what you're understanding in two dimensions is to three dimensions, so you can kind of build an intuition for something you don't even really understand. It's when you don't really understand the thing itself, if that makes any sense?

Andrew S.: Yeah.

Fatima A.: And then there's also the case that sometimes just math is where I put my trust in, like, "The derivation shows this, I have no physical intuition of this because nothing like it exists on earth, but I trust math pretty, pretty well."

Andrew S.: Yeah, that makes sense. Yeah.

Fatima A.: Yeah.

Andrew S.: You would say a lot of astronomy is putting faith in math?

Fatima A.: I mean, I would think a lot of physics, in general, is putting faith in math I think is the better way of putting it. Yeah.

Andrew S.: Would you say that you're like a math genius?

Fatima A.: No, not by any ... I would hope not, just because I don't want to be that arrogant at any point. But I mean I like math, but I also kind of think that math is just taught poorly and anybody could be good at math if they just had good teachers. You know?

Andrew S.: Yeah.

Fatima A.: I don't think math skills is anything remarkable, it's just kind of hard to acquire in the education system we live in.

Andrew S.: Right. So you think just about anybody could get ... The math isn't beyond anybody that wants to be an astronomer?

Fatima A.: No. I mean I ... This might just be like getting into philosophy and stuff, but I'm kind of of the belief that, I mean saying anybody can do anything is I sound a little bit like a motivational poster or something, but there's always this idea of math being this really inaccessible thing people are just born with the ability to do sometimes, and if you're not good with numbers, then you're not good with numbers. And that's this side of the brain, and I am good at that side of the brain or whatever it is.

But it's I think our education system is just awful. When it comes to STEM being a poorly taught thing is not a new idea whatsoever, right? I think math is just the most egregious example of that. There's just so many things that get people in today's society hung up about their abilities in math that just prevent them from learning from it, or being interested in it or anything. So yeah, I think anybody with the curiosity motivating them to study astronomy, if they had a good teacher or good resources and put their mind to it, would be able to learn the math necessary.

Andrew S.: Would you say that you had good math teachers? Is that kind of how you were able to get into astronomy?

Fatima A.: I kind of cheated. My dad's a physicist, so my success is very much just a function of the conditions that I grew up under, basically. I'm not a math genius. I am not any kind of special person in astronomy, I just like space a lot and have a curiosity about it. And I think that was very much fostered by my dad when I was young, and then that kind of just set me up to enjoy math a little bit more as a kid, especially.

Actually, people always were like, "Oh, you can just ask your dad for help on your homework," but that's actually a really awful thing to do and all my siblings would like make a joke about if you ask him anything he'll lecture you for hours, because he will just like go off onto ... As a third-grader I asked him a question about, "What's an exponent?" And then I got a several hour lecture on logarithms. I mean, that sounds not very complicated now, but as a little kid I didn't even know what the word was, and he was just talking at me and yeah, so that was always fun.

Andrew S.: And then you went into school and tried to explain logarithms and your teacher said, "Hey, we're doing exponents, please."

Fatima A.: You know what's actually funny? I'm like outing myself as a huge dork. I was in a math contest in middle school or something, maybe high school, middle school I think. And it was each week we had a challenge problem that we would take home for the, such a nerd, we would take home for the weekend and try to work out and see if anybody could come up with it the next week. And I remember there was one week that I was the only one who got it, but that's because I asked my dad to help me with it and basically, I don't know, it was like a statistics problem. And the way he decided to solve it for sixth grade me was using the Monte Carlo method, which I don't know if your listeners are familiar with statistical analysis, but this is not something you would do in sixth grade.

In fact, this is something that I only properly learned at grad school. But literally he just pulled out Excel and made a Monte Carlo simulator to simulate whatever little stats problem I had for this contest. And I went to school and presented this as the answer and they're like, "How did you do this?" I'm just like, "Oh, you know. I read a book."

Andrew S.: Why would the question even-

Fatima A.: I'm sure there was some other way to solve it, but that's just the thing he came up with when I asked for help, and it's just to illustrate the nonsense of those interactions if you would ask him for help on something, where it's just like way throwing more at the problem than is needed.

Andrew S.: Yeah. How was it going when you first got to your undergrad interacting with professors that weren't your dad?

Fatima A.: I mean, kind of nice because they were all used to answering questions and not needing three hours to answer it, you know? They prioritize their time. I mean, it was kind of nice because when I started studying physics, because in undergrad I started with physics, no astronomy. That came in later. It was kind of cool to constantly be surrounded by other nerds, because how it was in my house growing up or even now, whenever our family is together, it's like there's all the normal people in my family, and then me and my dad sit around in a corner and do math problems together. So now everybody was like that, you know, like everybody thought physics puns were funny, and everybody thought a really difficult riddle was a fun way to spend an hour.

Andrew S.: All of a sudden you were like the coolest kid in school.

Fatima A.: Right, right, right. I'm the coolest physicist person, which is a very, very low bar. No, I'm joking. That's not even true of the students I work with now. But yeah, if anything I've gotten too used to only being around other astronomers now. Because now it's like you go out into the normal world and you try to talk about something, something order of magnitude, and people are like, "What are you saying?" So I don't know.

Andrew S.: Yeah, I think if you started explaining gravitational waves, people would just kind of say, "Oh, okay. Yeah." Is that how most conversations mostly go?

Fatima A.: Well, because I get really, really into it ... If somebody was at my house and asked me that, I would pull out a whiteboard. I'm not joking. I actually have a whiteboard. It's huge. Everybody who comes through my apartment see it because, at some point, I'll compulsively need to explain something in great detail and I'll be drawing diagrams for you until you understand it, basically.

Andrew S.: So you're kind of like your dad now?

Fatima A.: Oh yeah. No, no, no. I'm a carbon copy. He just cloned himself.

Andrew S.: Nice.

Fatima A.: Yeah, it is what it is.

Andrew S.: Wait, so when you got to undergrad, I guess you were kind of like used to the whole academic environment, so was it pretty easy to get into research right away?

Fatima A.: I got into research, I mean I went to a really good school for research. I went to University of Maryland. It's remarkably easy for undergrads to do research there. They literally had a class in the physics department that's like, "If you sign up for this class, we'll teach you how to do research and then sign you up for a project with somebody." It was pretty straightforward. That was my sophomore or junior year of college. Sophomore year of college, yes. And I remember that very first project I worked on was actually also on black holes, even though I've done a bunch of different things in between now and then.

And it's basically the kind of thing, I think that once you get your foot in the door, you're just kind of like in it. Once you get that first research opportunity, then that's your jumping off point and you can apply to other internships for research positions, and then you have all this stuff for grad school, and then it's just snowballs, you know?

Andrew S.: Yeah.

Fatima A.: Yeah.

Andrew S.: Okay. But how did you decide to get here? Why did you pick Berkeley?

Fatima A.: Yeah, that's funny because it was such an afterthought. I had the same list of seven or eight grad schools I was planning on applying to for two years, and then a couple of days-

Andrew S.: Right. Was Berkeley one of them?

Fatima A.: No, it wasn't. And then a couple of days before the Berkeley deadline, I'm like, "What about this school? It looks kind of nice." That sounds like I have this really high ... I didn't get into all the Ivies or something, but it just never occurred to me to think of Berkeley for some reason. And it was weird because within the span of a couple of days, it went from being not on my several year long list to being the top of it. And it was a combination of really good astronomy program, cool area, blah, blah, blah, and for some reason, just over the course of a couple days I'm like, "Man, I really, really want to go to Berkeley."

And somehow it was the first place I heard back from, and as soon as I got that call and they're like, "Oh, you got in," I just emailed everybody else and I'm like, "Nope, not

interested," cut off the whole admissions process kind of early, which sounds kind of reckless and like I wasn't putting a lot of thought into my decisions.

Andrew S.: Wait, yeah. This is the person who makes spreadsheets. How does this happen?

Fatima A.: It's weird because I swear to God, I put so much thought, and effort, and energy and planning into the tiniest decisions, and then the really big ones are just like snap judgments whenever it hits me. You know?

Andrew S.: Yeah.

Fatima A.: That backpack I have over there? I literally spent two years shopping for that backpack.

Andrew S.: So do you have time to actually enjoy the Bay or do you spend a lot of time doing research?

Fatima A.: I think so. I think my department's really good about work-life balance for the most part. When I came and visited the school before I got accepted, I was really impressed by how much it seems like all the grad students had going on. I got to come visit and meet everybody and see what they're all doing, and besides the fact that they were all really cool and I wanted to be friends and work with them, they all ... I mean, half of them are super-serious rock climbers that go on all these climbing trips. So honestly, I feel like everybody has some really cool thing that occupies their time outside of research that they spend a lot of time on. And you don't really see people in our department sitting there until late hours of the night trying to get research done. It's really not that kind of energy, I guess, in our department, which is wonderful and I love ... Wait, what were you saying?

Andrew S.: I was just going to say, you don't stay up late into the night even though you look at stars?

Fatima A.: Because it's astronomy?

Andrew S.: Yeah.

Fatima A.: Actually, I do a lot. Not everybody who studies astronomy does that. It's only the observers. The theorists don't have to. But when I do do that, I don't wake up and go to work in the morning. I just switch, you know?

Andrew S.: Nice.

Fatima A.: I'm still, if I have to spend the whole night working, I'm just not going to work for two days after that.

Andrew S.: That's pretty cool.

Fatima A.: In the end it ends up even, even if some of us have really weird hours, which is super-fun.

Andrew S.: Wait, is there a telescope here on campus that you-

Fatima A.: So there is a telescope here on campus on the roof of our department. It's basically just for PR and teaching. The telescopes I use are primarily in Hawaii. Sometimes I get to go out there to use them because-

Andrew S.: Is that why you're an astronomer?

Fatima A.: You know, you would think like while you're an astronomer, you know you would think that that's ... I mean, it's nice because I do get to go out to Hawaii a lot, but observing sucks. I like astronomy and I'll endure observing for the end result, but people always imagine, "Oh, you're sitting outside at night looking through a telescope, how romantic," but in reality it's like you're on a mountain, it's 14,000 feet up, which means you're at 40% oxygen so you can't breathe. Well, you kind of can but it's basically the same amount of functionality as if everybody were drunk. And that's not an exaggeration. It's really awful being at altitude like that. There's oxygen tanks everywhere that we're all using the whole night, and you have to work at night.

Literally, I would get there to the summit as the sun is setting, work until sunrise, then go to sleep because the telescope has to be open to the sky, so you're basically outside. And if you're on a mountain that's 14,000 feet up, there is snow on the ground, so it's freezing. And then, because you can't have a light from whatever sources interfering with the telescope, you work in the dark. So it's dark, cold, middle of the night and you can't breathe, and you're just trying to do really intense, complicated work with really high stakes and I'll just have like a week of that.

Andrew S.: All right.

Fatima A.: Yeah. It's-

Andrew S.: That's doesn't sound like as fun as I thought [crosstalk]-

Fatima A.: It's not, but you know, Hawaii. That's the thing. I've gone down there and not seen the beach at all, or not seen sun except on the day that I arrive or something.

Andrew S.: Dang.

Fatima A.: Right? But sometimes I'll like be able to hang out a few days extra and make it worth it.

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Andrew S.: Well, so we've definitely talked for longer than these 30 minutes, and you can listen to the rest of the show on our podcasts on KALX's website. But as we wrap up, Fatima, is there anything that you would like to leave us with? The nature of science or reality?

Fatima A.: I mean, I think people always hear all that kind of thing about looking at the whole universe makes us feel very small, but it's also kind of beautiful because we're a part of it. Like the Sagan quote about star stuff, thinking about stars, like yes, we're a tiny, tiny bit of the universe, but we're also the same stuff that the rest of the universe is and are this crazy anomaly of things existing in mostly empty space. So yes, it's kind of existentially depressing, but it's also kind of beautiful and amazing at the same time that we could even exist in all of this. Yeah.

Andrew S.: Very true.

Fatima A.: Yeah, it's-

Andrew S.: Yeah, I feel better.

Fatima A.: I'm glad.

Andrew S.: Thank you.

Fatima A.: I'm glad. That was the goal.

Andrew S.: Today I have been speaking with Fatima Abdurrahman of the Department of Astronomy. We've talked about her research and her path to astronomy. I would summarize what we've talked about, but I'm still-

Fatima A.: It was a lot.

Andrew S.: Yeah, and it was a lot of stuff to process. So I'll just let you listen back to it on the podcasts. I'm Andrew Saintsing. Thank you so much.

Fatima A.: Thank you for having me. This was very fun.

Andrew S.: Tune into our next episode in two weeks.