ME: When you look up at the sky *now*–now that you've learned all that we've learned about the story of our universe–what do you see? Hopefully, you can imagine the vastness of the universe, that nighttime sky you probably took for granted before is full of billions, and billions, and billions of stars, on a scale so massive it's impossible for us puny humans on a tiny planet to imagine. And now that we've learned the story of how we came to know what we know, has that changed what you see, when you look up at the sky at night? Are there any features you never noticed before, that now you see every day?

MUSIC

ME: Hello and welcome to Cataloging the Universe! In this 7 part series, we'll be taking a journey through time and space to try to find our *own* answers to these giant questions about the universe. Along the way, we'll have some help from scientists, experts, and our imagination. I'm Marshall, and I'll be your guide on this journey.

This is Lesson 7: The Galaxy Zoo. In this lesson, we're going to help some present-day scientists answer their own big, big questions.

MUSIC ENDS

ME: For our last lesson, you're going to need a few supplies… your star journal, a pen or pencil, and a computer, iPad, or cellphone with access to the internet. If you've got all that, let's get started!

As you already know, once Shapley and Curtis resolved their disagreement, we learned not only that there were galaxies outside our own, but that there were billions and billions of them. So many that it was impossible to count. And although we've learned so much since Shapley and Curtis took the stage a hundred years ago, there are still a lot of things left to find out. That's why I time-traveled again to… like, a week ago. Where I talked to another astronomer, Karen Masters.

KM: My name is Karen masters. I'm a professor of astronomy and physics at Haverford college.

ME: Astronomers like Karen nowadays are trying to answer a *ton* of questions. She wants to know the answer to…

KM: Why galaxies are or are not forming stars.

ME: And also, about those spiral-shaped nebulae, she wants to know…

KM: How spirals form.

ME: And all around, what makes galaxies look the way that they do, and what that can tell us about the universe. Fortunately for Karen and other scientists like her, recently an enormous set of images of galaxies was published that scientists could work with, as part of an enormous "survey" of a huge portion of the night sky.

KM: The survey detected about a million galaxies that we thought we could measure distances to.

ME: This was great news! With all this data, scientists could try to answer an *enormous* number of questions they still had about the universe. Unfortunately, though, and you probably already know this, a million galaxies… well, that's a lot of galaxies to look at. Waaay too many for any one person to comb through. And in order to answer their questions, scientists really needed to look at every. Single. One.

KM: So all of a sudden we had this list, this database of million galaxies, all of which had images and all of which have distances. So we can understand lots about the physical properties of them. And Galaxy Zoo was very much inspired by a million galaxies is far too many for us to look at ourselves. Um, so we need help with that.

ME: The help they need, specifically, is in *classifying* galaxies. Ever since Hubble confirmed that there *were*, in fact, other galaxies outside of our own, scientists have known that there were different *types* of galaxies. They can be spiral–like the spiral nebulae–or they can be *elliptical*–which is a fancy word for oval-shaped.

Simply classifying galaxies can tell us a *lot* about the universe, including answering some other *big* questions like: How do stars form? How do galaxies change over time? And just how big is the universe really?

Karen and her team started digging into the millions and millions of galaxies in her dataset and tried to classify their shape and size. To do the work faster, first, they tried using a computer… but there were some problems.

KM: There's some movie where they confuse the computers by putting loaves of bread or dogs in front of them. And the computer can't tell the difference between a loaf of bread and a dog. So it just turns out to be really hard to analyze the shapes of galaxies with a computer. Whereas we've found that humans are just really good at identifying what they see in an image.

ME: This is where you come in! Using your perfectly normal, human brain, you can really help scientists answer these big questions just by telling them what kinds of stuff you see. Most likely, you can tell a loaf of bread from a dog–which means you're miles ahead of computers, and even if you don't know everything there is to know about galaxies you can still help quite a bit. In order to help, all you need is a computer with an internet connection, or a tablet, or a smartphone. Have you got any one of those? If so, go ahead and get them ready, and we'll get started!

PAUSE

ME: If you navigate to Galaxyzoo.org, the first thing you'll see is a pair of buttons–one that says "Learn More" and another that says "Get Started." Since I'm the kind of person who likes to just jump into things without reading the instructions first, I would always click on "Get Started" to begin with. If you click on this, you'll be shown an image of galaxy. I know it *looks* like it's just a smudge on the screen, but believe me–that's a galaxy, containing millions of stars, maybe millions of light years away.

PAUSE

ME: To help Karen with her research at Galaxy Zoo, I started classifying some galaxies that I saw. If you want, you can do the same along with me, or you can go ahead and work on it on your own, and then listen later. You can pause if you need more time.

PAUSE

ME: The first thing I saw once I got started classifying galaxies, was a fuzzy, blurry circle with a bright blob in the middle of it–probably not all that different from the images Messier observed through his telescope two hundred years ago and called "nebulae." When I first looked at it with Karen, we both agreed it was really cool.

KM: This one to me is really cool because it has features. It has a bright center and this line-like structure. So that's what we call a bar. And I can even see some

hint of spiral arms in this. So this is very much an example of a galaxy where you would click features or disk.

ME: Okay. And what do features or disks tell you as a researcher about the galaxy?

KM: The discs are telling us about how the stars are moving in this galaxy. It's literally shaped like a dinner plate. It's like a flat thing and all of the stars are going around in circles around on the plate, just like in the solar system. All the planets are orbiting the sun, and every star in a galaxy is orbiting around the center of the galaxy.

ME: Alright. So I clicked on, "It's got a feature or disc." So if it's an "edge on disc," what does that mean?

KM: Because these things are like dinner plates. If you catch them just edge on you just see a line in the sky, some of the most extreme examples of that literally just look like lines in the sky. You can't see the pattern on the dinner plate, right? If you see it edge-on.

ME: So if you're looking at an edge-on disc, that's like you're looking at the galaxy from the side. Not from the top.

KM: Exactly. And those galaxies are super interesting. There are all kinds of interesting stuff you can find out about galaxies when you see the edge-on like that. You can see what's coming up and down out of the plane of the disc. And you can get really good information about how the stars are rotating because of how we measure that. Whereas the galaxies where we see them face on it's much harder to get the motions of the stars.

ME (VO): My galaxy *wasn't* edge-on, so I clicked on to the next thing, where Galaxy Zoo asked me if I saw any bars in my galaxy. But what do bars mean?

KM: **So bars are really interesting features. They're a little bit like traffic jams in stars and they're a little bit like: it's like they're a traffic jam, but also a super highway. They're kind of like a way for stars to move inwards and outwards in the galaxy. You're more likely to find really strong bars, like the one in this example, like really obvious bars, you're much more likely to find them in older galaxies,**

older disc galaxies. So they seem to have something to do with how galaxies turn off forming stars.

ME: Okay. I'm gonna go ahead and click "Strong bar."

KM: I think that's what I'd click too.

ME: And "is there any sign of a spiral arm pattern?" So what does it like if you can see a spiral versus not, what does that tell you about the galaxy?

KM: So again, spirals are to do with the motions of the stars. They're kind of like waves and or little traffic jams in where the stars are going around in the galaxy. We tend to see spirals in galaxies that are forming new stars right now

ME: So it seems to be like how active they are in forming new stars. Do we know for certain, what makes a galaxy form stars or not?

KM: Well, I mean, that's like one of those questions that's an active research question. I'm here at a conference this week and I think there are eight different sessions on the evolution of galaxies and every single one of those sessions is gonna talk about why galaxies are or are not forming stars.

ME: (Laughs) The universe is amazing!

KM: It's kind of cool!

KM: This is the progress of research, right? There are different pieces of the puzzle and we're trying to put it all together. And like I said, galaxies are complicated and diverse. So one person finds some set of galaxies and they're like, "Aha, this is the answer!" But it turns out that's probably just the answer for their set of galaxies. A different set of galaxies might have a different answer. And so that can lead to some interesting discussions and trying to figure out what's different about the galaxies that you're looking at.

ME: As you look at these tiny smudges on the screen, remember: you're looking at distant galaxies. Take a minute to think about just how vast the universe is, and how many more times bigger we now think it is, compared to what people living just a little more than a hundred years ago did. In this series, we've told the story of how we came to understand just how huge the universe is, how full of stars and galaxies it is, and how

much more of it there still is to understand. In fact, one of the users of Galaxy Zoo, a person just like you, made what turned out to be a major discovery using the platform. One of the volunteers had seen something strange, a bluish-green blob, and thought, “Huh. What’s that?”

KM: It turns out it was a light echo from an accretion from a supermassive black hole at the center of the galaxy. So the galaxy that was near that blue blob used to have a black hole that was accreting stuff, and so that black hole was very bright.

And that light was traveling through the universe and it basically lit up this gas cloud. And that takes time because light takes time to travel and there was some distance between the center of the galaxy and this clump of gas. And in the time that light was traveling, the black hole stopped accreting material and stopped making light. So we just see the cloud lit up from the leftover light.

Isn’t that cool?!

ME: (Laughs) It’s amazing! It's so cool!

KM: I love that one. And it was found because someone looked at an image and was like, “That's a weird blue blob. What's that weird blue blob?”

ME: Wow. Yeah. All right. Well, I see no weird blue blob, so nothing unusual here. And then that gets me to the end of the chain.

KM: Yeah, that's right. And we go to the next galaxy right away.

MUSIC PAUSE

ME: Who knows, maybe something you identify could be part of the great next discovery. As we have learned every bit of knowledge counts.

PAUSE

I hope you’ve enjoyed going on this journey with me! When you’re done listening to this episode, we have a few extra worksheets to complete about your experience with Galaxy Zoo, and asking about all the other things we’ve learned in this series. Which is hopefully so much!

PAUSE

ME: This educational audio course was written, produced, and hosted by me, Marshall Escamilla. I had editing help from Sara Robberson Lentz and Lindsay Patterson. We had production assistance from Elliot Hajjaj, our Tumble Media Intern. Hamish Johnson did the voices of Harlow Shapley, Heber Curtis, and Charles Messier. Sara Robberson Lentz did the voice of Henrietta Leavitt. Thanks so much to Dhanesh Krishnarao and Karen Masters for advising on this project and providing their invaluable expertise. DK, and this audio course, is supported by an NSF Astronomy and Astrophysics Postdoctoral Fellowship under award AST-2102490. Thanks so much for listening, and we'll see you in outer space!