[MUSIC PLAYING]

MOLLY BLOOM: You're listening to *Brains On* from NPR News and Southern California Public Radio. We're serious about being curious. I'm Molly Bloom.

Have you ever wondered what's beyond the edge of the universe? Or maybe a better question-- is there even an edge of the universe? And what does it mean that the universe is expanding?

We're about 15 seconds into this episode, and my brain already hurts from thinking about these big questions, so it's a good thing that we have help. Today, we're going to be listening in on a conversation between two very smart people who are wrestling with these very big and very blowing questions. The first is an astrophysicist.

KATIE MACK: Hi, my name is Katie Mack. I am a theoretical astrophysicist, and I study the early universe and dark matter and stuff like that. And I live in Melbourne, Australia. And I work at the University of Melbourne.

MOLLY BLOOM: And the second is Thea Hutchins.

THEA HUTCHINS: Hi, my name is Thea. I'm nine years old, and I live in Sydney, Australia.

MOLLY BLOOM: Thea wrote what is perhaps our favorite email that has ever been written to *Brains On.*

THEA HUTCHINS: I don't understand how the universe can be expanding into nothing. Like, what is the nothing that the universe is growing into? Also, before the Big Bang, there was nothing, so what made the bang? Usually, explosion is blowing up something, but there was nothing to blow up.

How can everything have come from nothing? What is nothing, anyway? How can there be no space? I can't understand how to think about nothing. Too many questions. Thanks, Thea.

MOLLY BLOOM: In our book, too many questions is always a good thing. We arranged a conversation with Thea and Katie, and we are very excited to share it with you. Now, we can all stare into the infinite together.

Thea started by asking about the expansion of the universe.

THEA HUTCHINS: I understand how the universe can be going and can be expanding into nothing. Like, what is the nothing that the universe is going into?

KATIE MACK: There's nothing that we see that indicates that there's any edge to the universe. We can't see forever. As far as we can see, the universe doesn't seem to be ending. There's nothing that says that, when we look really far in one direction, that we see a wall or anything like that there. Seems to be just no edge.

And if there's no edge, if it really does go on forever-- which we don't know-- then it could go on forever, and it could be just getting bigger, even though it's already infinite. It could be getting more infinite, sort of.

And that's a weird idea, but really, all we see is that we see that galaxies are moving apart from each other. Distant galaxies are getting farther apart from other distant galaxies, and they're getting farther apart from us. And so all we really can say is that things in the universe are getting farther apart from each other, and we interpret that as the space in between is expanding. And it really looks like all of space is expanding.

I mean, the galaxies themselves are not getting bigger, but the spaces in between them are. And so it's possible that the universe is already infinitely big. There are lots of galaxies in this already infinitely big space, but the galaxies in this big space are getting farther apart from each other.

And that's something you can do in an infinitely big space. You can have everything in the infinitely big space getting farther apart from each other, which would be like the infinitely big space getting more infinitely big.

THEA HUTCHINS: Yeah.

KATIE MACK: And so that's totally possible, and that's consistent with all our observations. It could also be that the universe kind of wraps around itself at some point. So like if you're on the surface of a balloon, and the balloon is being blown up, from the surface, there's no center of that expansion. Different points on the surface are just getting farther apart from other points on the surface.

It could be something like that, but we don't know at the moment. And if it were like that, then that would be a really big balloon.

THEA HUTCHINS: Yeah.

KATIE MACK: Because as far as we can tell, we can't see that curving around. To us, the universe doesn't seem to be wrapping around on itself. But that could just be that it's doing it on such a large scale that we can't see it. So either of those things are possible.

And in one case, you don't need any space outside of our universe. And in the other case, you do. But in both cases, all we really see is that things in the universe are getting farther apart.

[SLOW GUITAR AND BASS MUSIC PLAYING]

THEA HUTCHINS: When I heard that the universe is always expanding, and-- I thought about, if you go to the edge of the universe-- if there is an edge of the universe-- then I would think the universe is just this square of black, and then there's white around it. Like if you get to the edge of the black, then there's just white-- empty white, like infinite white.

KATIE MACK: There was an interesting discussion about this back in the ancient times. I don't remember who the people who were talking about this, but they were talking about the edge of the universe. And they had this sort of thought experiment. A thought experiment is where you can't do the experiment, but you can think about it, and you can talk about what would happen.

And they were saying, what if you go to the edge of the universe, and you take an arrow-- like a bow and arrow-- and you shoot the bow and arrow? You shoot the arrow off the edge of the universe. Then, that arrow has to go somewhere, and that somewhere must be part of the universe.

And so then, the universe isn't-- there's not an edge of the universe. Then, that can't be the edge.

THEA HUTCHINS: Yeah.

KATIE MACK: Because the arrow went somewhere else. And then, so they were thinking like, well, what if you just keep doing that? Then you can't ever have an edge.

I think that there could be an edge based on the way that we think about physics and dimensions now, because there could be a limit to our dimensions of space. Like we have three dimensions of space. We have up and down, and left and right, and front and back, right?

THEA HUTCHINS: Yeah.

KATIE MACK: It could be that like you can't go-- one of these directions doesn't go forever, or maybe all of the directions don't go forever. And then, there really could be an edge. I don't know what color it would be. We don't know that. And it might be that like you'd have to find some other direction to shoot your arrows into [LAUGHS] that we haven't invented yet.

But yeah, I mean, it's totally possible that there is an edge. And you know, yeah, I don't. But I have no idea what it looks like. And it's interesting; I never thought about it as white. I always think about it as black.

THEA HUTCHINS: Yeah.

KATIE MACK: But yeah, that's cool.

[SLOW GUITAR AND BASS MUSIC PLAYING]

MOLLY BLOOM: What do you visualize when you think about the universe or the Big Bang? Send us a drawing. We would love to see it. You can email it to *Brains On* at M, as in Minnesota, P-R dot org, or you can find our mailing address on our website, brainson.org. We're going to take a short break from pondering the mysteries of the universe to mull over a more bite-sized one. It's time for the mystery sound.

[THEREMIN BLOOPING]

VOICE: (WHISPERING) It's a sound!

MOLLY BLOOM: Here it is.

[LOW VAMPING MOTOR SOUND OVERLAID WITH A LIGHT SHARP CLACKING]

Any guesses? Let's hear it again.

[SOUND REPEATING]

We'll be back with the answer right after this.

[BRIGHT MUSIC PLAYING]

We have loved seeing your photos from the Great Outdoors this summer. You've shared photos from the Grand Canyon, Mount Rainier, and Zion National Park, to name a few. Someone even sent us an amazing video of dung beetles from Theodore Roosevelt National Park. We'd love to see more. Just share your photos of your summer adventures on social media and tag us @brains_on, or you can use the hashtag #BrainsOnParks. We'll be sharing our favorites on social media all summer.

And now it's time for the Brains Honor Roll. These are the kids who keep the show going with their ideas, mystery sounds, drawings, and high fives. Here's the most recent group to be added to the Brains Honor Roll.

[ENERGETIC BASS-HEAVY MUSIC PLAYING]

[LISTING HONOR ROLL]

ROBOT VOICE (SINGING): Brains Honor Roll, Bye-Bye.

MOLLY BLOOM: Let's get back to that mystery sound. Here it is one more time.

[SOUND REPEATING]

Here's a hint. If you're listening to this podcast in the car, you might have been hearing this in the background all along. Ready for the answer? Here's Gabriella from Lorton, Virginia.

GABRIELLA: Hi, my name is Gabriella. I'm 9 and 1/2 years old, almost turning 10, and my mystery sound was the signal on my mom's car. We use the signal to keep safe. Bye!

MOLLY BLOOM: Now that we have that mystery taken care of, we're all ready to wrap our minds around the Big Bang, right? Here's Thea.

THEA HUTCHINS: Before the Big Bang, there was nothing, so what made the bang? Usually, explosion is blowing up something, but there was nothing to blow up. How can everything here come from nothing?

KATIE MACK: People usually imagine the Big Bang as an explosion. And that's how it's usually drawn, or animated, or whatever. But that's not really very accurate because an explosion is like a ball of fire happening in a bigger space, and it expands out.

It's possible that the universe started in like an infinitely dense point, but it's not really like a point in a larger space. It's like all of space would have been wrapped up tighter. So if you imagine that balloon I was talking about, if you imagine, take a balloon that you haven't blown up yet, and crumple it up into a little ball, and then you start blowing it up, and the surface of the balloon gets bigger and bigger, points on the surface are getting farther apart from each other, but every point on the surface was at the center at the beginning.

So that's one way you can think of the Big Bang-- that every part of the universe was the center of the universe, and every part of the universe is moving away from every other part of the universe as it's getting bigger. But it's not like an explosion in a larger space, necessarily. And we don't even know for sure that that singularity, that infinitely dense point, happened.

What we do know is that there was a time very, very early in the universe where the universe was expanding really, really quickly, and we call that inflation. And that sort of kicked off this expansion of the universe that was-- first, it was extremely fast, and then it slowed down. And since then, it's been slowing down, except that recently, it started speeding up again, which is a whole other topic. [LAUGHS]

THEA HUTCHINS: Just one more question. What is nothing, anyway? How can it be no space?

KATIE MACK: Yeah, so one of the ideas behind this concept of the singularity, the sort of infinitely dense point, one idea behind that is that there was that point that was the beginning of space and the beginning of time. So in physics, we talk about space-time, where space and time are kind of wrapped up together and the way you move through space affects how you move through time. And so it's this kind of weird space-time fabric, right?

So there's an idea that, at the very beginning, the singularity was the beginning, the origin, the thing that created both space and time. And if that was the case, then outside of that point, or before that point, there wouldn't have been either space or time. So you couldn't really call it before. There was no before because time hadn't been created yet. [LAUGHS] You know?

And the thing is, nobody knows how to do that in terms of what could create that stuff. This is still an area of research where we try and think about what could have happened before the Big Bang, if there was a before. Maybe there was a sort of big crunch, and then a bang, and then a crunch, and then a bang, sort of expanding and collapsing. That might be the case.

There could be all these-- there are these different models where there's a parallel universe, and we smash into the parallel universe, and that creates the Big Bang. And then, the two universes come apart for a while, and then they come back together. And in those kinds of situations, there can be spaces in dimensions other than our own dimensions-- like directions we can't access. And those spaces might have something in them or might not.

But in terms of nothing, it's kind of hard because in our concept of our universe, there isn't anything that's like-- there's no nothingness because even empty space, even the vacuum of space, has energy in it. We call it the vacuum energy. There's little virtual particles being created and destroyed all the time.

And so there kind of isn't nothing in our universe. But it might be that there was a time when the whole universe sort of began, and there could have been-- and if the universe had a beginning-- like a true beginning where there was nothing before that-- then there was nothing before that, I mean. [LAUGHS]

THEA HUTCHINS: Yeah.

KATIE MACK: And so you could say that nothing is anything outside of our universe, but you could also just define the universe as being everything and the entirety of what we can think about. So like a lot of times in physics, when we talk about things that we can't observe, we don't really have a lot to say about those because physics is all about having an idea and then testing it with the data and trying to refine these theories by comparing them to data. And if we don't have any data, then that's really hard to do.

And then, it's hard to know if that's even science because it's just speculation. So we know that there are parts of the universe that we'll never be able to observe, and we know that there are times in the universe, like the first moments of the universe, that we don't have any information about. And so it's hard to really do any science about those things. And that's where the nothing would be.

THEA HUTCHINS: Yeah. [LAUGHS]

KATIE MACK: If there were really nothing. So we kind of avoid that because it's so hard to learn about.

THEA HUTCHINS: Yeah.

KATIE MACK: That's the fun part about theoretical physics, though. It's that I really like the brain hurting part. That's kind of why I do this.

[SLOW GUITAR AND BASS MUSIC PLAYING]

MOLLY BLOOM: That's it for this episode of *Brains On. Brains On* is produced by Marc Sanchez, Sanden Totten, and me, Molly Bloom. Don't forget our National Parks Project. Send us your pictures and drawings of you in the great outdoors. Use the hashtag #BrainsOnParks.

And before I go, we also want to give a big mazel tov to Sanden on his wedding and officially welcome Kathy to the *Brains On* family. We'll be back with more answers to your questions very soon. Thanks for listening!

[TAPE RECORDING REVERSING RAPIDLY]

CHILDREN: Brains On!