SPEAKER 1: You're listening to *Brains On,* where we're serious about being curious.

SPEAKER 2: *Brains On* is supported in part by a grant from the National Science Foundation.

[SHEEP BAA-ING]

SANDEN TOTTEN: OK, Menaka. Next is a 1972 Ford Pinto.

MENAKA WILHELM: On it.

[BUZZING]

And there.

[CAR HONKING]

MARC SANCHEZ: Impeccable. Look, there's even a little radio antenna.

[BOING]

OK. Eiffel Tower, go.

MENAKA WILHELM: Oh, wow. OK.

[BUZZING]

There.

MARC SANCHEZ: Ooh, la la. I feel like I'm in gay Paris.

SANDEN TOTTEN: OK, this one is really tough. Tennis superstar Venus Williams in the year 2000, the exact moment she won at Wimbledon, making her the first Black woman to do so since Althea Gibson in 1958.

MENAKA WILHELM: Gosh. OK, hold on.

[BUZZING]

Almost have it. Wait, one more thing. There.

[THWACK OF TENNIS BALL]

[CHEERING]

SANDEN TOTTEN: Wow. You even caught the beads of sweat on her forehead? Truly amazing, Menaka. Wow, you are so ready for this.

MOLLY BLOOM: Hey, Sanden, Marc, and Menaka. Wait, why are all these sheep here? Whoa, these sheep are shaped into such super showy shapes.

MARC SANCHEZ: Menaka's practicing for a sheep shearing school.

MENAKA WILHELM: Yeah, sculpting sheep shags into showy shaves is a section of my sheep shearing school scholarship.

MOLLY BLOOM: Whoa, is that tennis superstar Venus Williams the moment she won at Wimbledon, making her the first Black woman to do so since Althea Gibson in 1958, shaved from a sheep's wool?

MENAKA WILHELM: Sure is.

MARC SANCHEZ: You know, Menaka, I am so psyched you're sailing off for sheep shearing school in Sheffield. Sheep shearing is such a surefire showstopping skill. But I'm shad, I mean, sad that you'll be leaving us.

SANDEN TOTTEN: Shame here. I mean, same here.

MOLLY BLOOM: We chipped in and got you this going away present. Here.

[UNWRAPPING GIFT]

MENAKA WILHELM: Oh, wow. A new scooter and a fresh set of yoga togas.

MOLLY BLOOM: Yeah, we hope they'll make you think of us when you're showing up to shore up your sheep shearing skills at sheep shearing shchool-- school.

[CRYING]

MARC SANCHEZ: And don't forget to write and email [SOBBING] and send texts and little selfies [SNIFFLING] and postcards and telegrams and Morse code and carrier pigeons.

MENAKA WILHELM: Oh, I will. I'll keep in touch. And here, I wanted to leave you with something, too. Hold on one sec.

[BUZZING]

There.

MOLLY BLOOM: Oh, my gosh. Is that you shaved into the shag of a shaggy sheep?

MARC SANCHEZ: Wow, our very own sheep shag sculpture of Menaka. I love it.

MENAKA WILHELM: Just make sure to feed and water the sheep it's attached to. Well, I better ship off to sheep shearing school shoon.

MARC SANCHEZ: Oh, one more hug.

SANDEN TOTTEN: Good luck out there, Menaka.

MOLLY BLOOM: Yeah. Now go show that sheep shearing school what a sheep shearing sharpshooting superstar you surely are.

MENAKA WILHELM: Will do. Shee you later, Brains On.

[MUSIC PLAYING]

MOLLY BLOOM: You're listening to *Brains On* from APM Studios. I'm your host Molly Bloom, and I'm joined by Uma from Ojai, California. Oh, hi, Uma.

UMA: Hi.

MOLLY BLOOM: We are so happy to have you here today. So today's episode is all about how we're connected to stars, and it was inspired by this question from Ramona.

RAMONA: My name is Ramona from Lexington, Kentucky. My question is, how are we related to stars?

MOLLY BLOOM: I love this question. And Uma, I heard that you want to become an astronomer, someone who studies space.

UMA: Yeah.

MOLLY BLOOM: When you're a grown up. Can you tell me more about what got you interested in space?

UMA: Sure. I want to become an astronomer because I have so many questions that I want to answer.

MOLLY BLOOM: How did you first get interested in space and stars?

UMA: My mom and dad got a space book for me and, I really liked the concept of life on a different planet. And I hope that someday we can land on Mars and live there.

MOLLY BLOOM: And so have you heard about supernovas?

UMA: Yeah. So they usually occur when like a giant or supergiant star explodes and dies.

MOLLY BLOOM: You're totally right. So when you think about supernovas, how-- what do you think about them?

UMA: I think it'd be cool to witness one.

MOLLY BLOOM: Before we get to answering Ramona's question about how we're related to stars, let's review what stars are.

UMA: Stars are giant balls of burning gas that float out in space.

MOLLY BLOOM: They start to form when gravity pulls clouds of dust and hydrogen together. As all that dust and hydrogen piles on, pressure and heat start to build.

UMA: And soon all that pressure transforms the hydrogen into helium, which creates a bright shining star.

[CHIMES]

SPEAKER 3: 'Tis I, a star. See how I twinkle. See how I sparkle. It's totally cool if you're in awe of me. I'm amazing.

MOLLY BLOOM: Voila, a star is born. And stars burn off lots of light and heat.

UMA: So much light that we can see them even from really, really, really far away.

SPEAKER 3: Hello to all my adoring fans out there across the vastness of space.

MOLLY BLOOM: It can be hard to wrap your head around it, but some stars are trillions and trillions of miles away.

UMA: Trillions with a T? Whoa.

MOLLY BLOOM: I know, totally bananas. And since they're so far away, the light from those stars takes years and years to travel through space and reach our eyeballs.

UMA: Double bananas.

MOLLY BLOOM: But there's one star we're very familiar with that's only a few millions of miles away, so pretty close cosmically speaking.

UMA: The sun.

MOLLY BLOOM: Right. Our sun is the closest star to us here on Earth.

UMA: So far, yet so close.

MOLLY BLOOM: And stars can shine for millions, even billions of years. But they can't shine forever.

UMA: Yeah, at some point they retire, settle down, and really get to enjoy their hobbies. They can finally start learning to crochet.

MOLLY BLOOM: No, not quite.

UMA: Oh, right.

MOLLY BLOOM: Eventually stars run out of fuel and burn through all that gas, slowly fading away. This process can take a really, really, really long time. And it all depends on how much mass a star has.

UMA: Mass is the amount of stuff something contains, like all that gas.

MOLLY BLOOM: Exactly. And all that stuff, that mass, is creating pressure that pushes out against gravity. It's kind of like a pressure filled arm wrestle. On one team you've got the star and all its mass pushing outwards.

[CHIMES]

SPEAKER 3: I am mighty, and I will not be crushed by gravity. Watch me flex outward. See? [GRUNTS]

UMA: And then there's team gravity trying to push all that mass inwards.

SPEAKER 4: Star, try as you might, you cannot escape me, Gravity, but go ahead. I like a challenge.

MOLLY BLOOM: And so as that star is burning through its fuel, it starts to lose that pressure that's pushing out.

SPEAKER 3: Oh, all this burning and shining, it's exhausting. I mean, I'm running out of steam here.

UMA: And before you know it, gravity starts to take over the star.

SPEAKER 4: Don't feel bad, star. Gravity always wins, but hey, you did your best. Let's hug it out. Come into my all-encompassing, crushing grip.

SPEAKER 3: Oh, wow. I'm being crushed, but it's surprisingly comforting. You are good at hugs, Gravity.

SPEAKER 4: I know.

MOLLY BLOOM: The star's core collapses, and in a fraction of a second, that creates a big reaction.

UMA: Boom. The star explodes.

MOLLY BLOOM: And that explosion is called a supernova.

UMA: Or supernovae when there's more than one, or you can call them supernovas. Either works.

MOLLY BLOOM: And a star can only create a supernova if it has a lot of mass. We're talking way more mass than our sun.

UMA: Now that's massive.

MOLLY BLOOM: And that's our stellar recap.

THEME SONG: Brains On. Star. Star.

[DOOR OPENS AND CLOSES]

MARC SANCHEZ: Oh, wow. This is amazing.

MOLLY BLOOM: Hey, it's our pal Marc Sanchez with a very large book.

UMA: Yeah, speaking of massive, that's a lot of pages. What's that, Marc?

MARC SANCHEZ: Oh, hey, Molly. Hey, Uma. Check it out. Yeah, I ordered this super cool book from ancestars.com. It traces my family history all the way back to the stars.

MOLLY BLOOM: Which stars? Charlie Chaplin, Captain Hook, Arthur Fry, inventor of the Post-it note?

UMA: Not that kind of star, Molly. The kind up in space.

MOLLY BLOOM: Wait, you're related to space stars?

MARC SANCHEZ: Dude, we all are. Check this out.

[TURNING PAGES]

OK, this is me.

UMA: Aw, that's a cute baby picture. Look at your little bonnet.

MARC SANCHEZ: And here's my parents and my grandparents, my great grandparents.

MOLLY BLOOM: Oh, look. 2 million years ago, the beginning of the human family tree, and 65 million years ago, the beginning of mammals. Whoa. This goes really far back.

MARC SANCHEZ: Yeah, and when you go all the way back--

[TURNING PAGES]

UMA: Whoa. It's a picture of a star, an exploding star, an exploding star that shoots out all kinds of stuff into the galaxy.

MOLLY BLOOM: Yeah, we just talked about how really big stars can run out of fuel and suddenly collapse thanks to gravity.

UMA: And when that happens, kaboom.

MARC SANCHEZ: Right, kaboom! But get this, when stars are still burning, they create all kinds of important materials in their big starry bellies. Stuff like iron, calcium, and silicon, all things that are created through lots of heat and pressure.

MOLLY BLOOM: Cool. Stars are stuff factories. They are pretty and functional.

MARC SANCHEZ: Totally. They cook these materials for millions and millions of years. And when they finally explode, all that important star stuff gets flung out into space like confetti.

UMA: So like a pinata?

MARC SANCHEZ: Yeah, stars are space pinatas. I love it. And then over millions of years, that star confetti can eventually squish together to create its own gravitational field. And that helps to form new stars or even a planet like Earth.

UMA: So Earth is made of star confetti?

MARC SANCHEZ: Yep, and if a planet is really lucky, it might have the right combination of star confetti in it for simple organisms to form. Then those organisms might evolve and create more complex living things. And then those evolve into other things and so on and so on until you get things like bacteria and moss and dinosaurs and mammals and me, Marc. Super-duper, extra, great, great, great grandson to a star.

MOLLY BLOOM: Wow. You're made of star stuff, Marc.

MARC SANCHEZ: That explains my awesomeness.

UMA: And modesty.

MARC SANCHEZ: Oh, no, it's not just me. It's all of us. We're all made of star stuff.

UMA: Whoa. I think I'm star struck.

MOLLY BLOOM: Me, too. Let's take a quick break to refuel.

[MUSIC PLAYING]

We're working on an episode about telekinesis. That's the word used to describe the super power of moving things with your mind. If you had this superpower, what would you use it for? What about you, Uma?

UMA: I would use it for cleaning up my room without getting off the couch every day.

MOLLY BLOOM: Nice. Maybe some multitasking, keep watching TV while cleaning your room.

UMA: Yeah.

MOLLY BLOOM: Listeners, you can send a recording of your answer to us at brainson.org/contact. While you're there, you can also send us mystery sounds, drawings, and questions.

UMA: Like this one.

JOSEPH: Hi, my name is Joseph from Indianapolis, Indiana. My question is, why do hot sauce make your nose run?

MOLLY BLOOM: You can hear an answer to that question by listening to the *Moment of Um* podcast. That's our new bite-sized daily podcast. You can find it wherever you listen to *Brains On.*

UMA: Just search for *Moment of Um* and keep listening. You're listening to *Brains On* from APM Studios. I'm Uma.

MOLLY BLOOM: And I'm Molly. We've been talking a lot about stellar explosions, but are you ready for a sonic boom? It's time for the--

[MYSTERIOUS SOUND]

UMA: (WHISPERING) --mystery sound.

MOLLY BLOOM: Here it is.

[MYSTERY SOUND]

All right. Uma, what are your thoughts?

UMA: I think it sounds like somebody's stapling a piece of paper and-- like, while in a car.

MOLLY BLOOM: Yeah, there was a lot of noise, wasn't there?

UMA: Yeah.

MOLLY BLOOM: Well, that's very good listening. We're going to have another chance to guess, and we'll hear the answer after the credits at the end of the show.

THEME SONG: Ba ba ba, ba ba, ba ba, ba ba ba, Brains On.

MOLLY BLOOM: OK, so we've been talking about how super awesome supernovas are.

UMA: Yeah, massive stars exploding. Galactic-tastic.

MOLLY BLOOM: And without supernovas, we wouldn't be here. All that explosive pressure and heat created the elements that make up everything we know.

UMA: Our galaxy, Planet Earth, your house, your shoes, your favorite book, you were all made up of stardust. So it's pretty important to understand how supernovae work.

MOLLY BLOOM: And even though we understand a lot of the incredible things supernovas do, they're still pretty mysterious.

UMA: Right. Like, do we even know when a star is about to explode? Do they come with countdown timers?

MOLLY BLOOM: No. It's super rare for astronomers to witness a supernova in real time, let alone predict when a star will go supernova. Instead, they use big telescopes that scan the skies for new supernovas, stars that have already exploded. And we talked to someone who does just that.

WYNN JACOBSON-GALÁN: Hi, my name is Wynn Jacobson-Galán. I am a graduate student at UC Berkeley, and I study stellar explosions.

UMA: Also known as supernovas.

WYNN JACOBSON-GALÁN: I think my job, it is like a-- it's a two-part process, but one would be like a stellar mortician.

MOLLY BLOOM: A mortician is someone who works with dead bodies. But in Wynn's case, it's dead stars.

WYNN JACOBSON-GALÁN: I'm kind of digging through the graveyards of stellar death because I'm looking out. I'm finding supernovae, but supernovae are technically the deaths of stars. So I'm always looking at stellar death. And then I'm trying to link it back in a detective sense or in a forensic sense.

So as another part-time job would be a star detective or a forensicist who's using clues about the death that I witnessed, this supernova, this explosion, to then kind of put the pieces back together to say, OK, this star exploded this way, and it produced this supernova.

UMA: Wow. A part-time grad student, stellar mortician, and star detective?

MOLLY BLOOM: A total triple threat. And since it's super rare for astronomers to catch a star before it goes supernova, Wynn's research starts with the explosion, and then he works backwards to try and figure out why that star exploded in the first place.

WYNN JACOBSON-GALÁN: The way I go about studying this is I do it indirectly. So I look at the supernova that results, and then I try to wind back the cosmic clock and try to make some predictions about what star produced that supernovae, kind of digging up information as I can without seeing the star itself before it exploded.

UMA: Wynn relies on telescopes to search for any big changes in the stars.

MOLLY BLOOM: And there was one case in particular that was very mysterious.

UMA: It all started with a strange glow.

[MUSIC PLAYING]

MOLLY BLOOM: It was the summer of 2020, and Wynn was working with this giant super-powerful telescope that scans the sky every night. It observes on its own and takes pictures of as much of the sky as possible.

WYNN JACOBSON-GALÁN: So this telescope's doing this thing every night. It's doing its job very well. And in the summer of 2020, it observes something a little peculiar. It observed a bright-ish source in a galaxy pretty far away at 120 million light years. So pretty far.

MOLLY BLOOM: That's trillions and trillions of miles away.

WYNN JACOBSON-GALÁN: And so it's in this distant galaxy. It sees this kind of luminous-ish source, so pretty bright. And it wasn't there the night before. It wasn't there years before, but just in the summer it kept observing this luminous radiation which we weren't quite sure what it was.

UMA: Hm. So a mysterious glow in a faraway galaxy just appears out of thin air? Very interesting. What say you, Bloom?

MOLLY BLOOM: Agreed, very strange. But to Wynn and the other researchers, this glow was nothing to write home about. I mean, this was no supernova, just some strange glow.

WYNN JACOBSON-GALÁN: And we didn't think much of it. There's a lot of other explosions going on. We can't be concerned about some possible source in some faraway galaxy.

UMA: So the researchers went about things as usual, but the telescope was still watching. And day after day, the glow continued. That is, until--

WYNN JACOBSON-GALÁN: And then after 130 days or so--

[EXPLOSION]

--a supernova appears. And we saw the supernova, and that supernova happened to be at the exact same location as this luminous point of radiation. And we didn't quite put two and two together. We were just excited about the new supernova.

UMA: Good golly, Molly. A supernova. So they just happened to see this star explode by chance?

MOLLY BLOOM: Yeah, it was a big coincidence.

WYNN JACOBSON-GALÁN: We got really excited about it, and we observed it with other telescopes around the world. And it was this type of supernova that we knew came from the explosion of a very massive star called a red supergiant.

UMA: Red supergiant? What's that?

WYNN JACOBSON-GALÁN: Red supergiants are these really puffed up kind of cool but still very hot massive stars 10, 15, 20 times as massive as our sun. And they are really nice stars to produce supernovae because they are massive. They'll burn all their elements in their core, and they'll collapse and produce supernovae.

MOLLY BLOOM: Right. And up until that point, scientists knew these red supergiants would explode, but they would be fairly quiet before then.

WYNN JACOBSON-GALÁN: They're kind of timid before they explode. They're not doing too much to give off a lot of light. They're not doing a lot to maybe eject material. They're not throwing off a lot of gas before they explode. And the really cool thing was putting the two pieces together.

UMA: OK, we've got two clues here, a strange glow and a supernova, all in the same spot. But what does it mean?

WYNN JACOBSON-GALÁN: We concluded, OK, this supernova, it came from the collapse of a red supergiant star. So that's what we know.

So then if I know that about the supernova, and I think that the star was a red supergiant, then maybe what I saw before the supernova at the same location is actually the red supergiant itself producing this bright luminosity or radiation that we've never seen a red supergiant produce before going supernova.

UMA: Star detective hard at work.

MOLLY BLOOM: Right, and this was super exciting.

WYNN JACOBSON-GALÁN: From my point of view, it's really cool because we'd never seen this before. We know that red supergiants produce these explosions. We never detected one before it exploded. So that's a first, and then now we get to go out and try to find more events like this.

MOLLY BLOOM: Wynn and his team now might have a clue they can look for to find a star before it explodes which means they might be able to watch more stars go supernova and learn from them.

UMA: Yep, and just like that, the case of the mysterious glow is closed.

[MUSIC PLAYING]

MOLLY BLOOM: Well, sort of. This is really the beginning to understanding more how supernovas work and what stars do right before their very end. There's so much more to be discovered.

UMA: So you're saying there's more mysteries to be uncovered?

MOLLY BLOOM: Tons.

UMA: Whew. I was really worried Wynn would be out of business. Thank my lucky stars.

[MUSIC PLAYING]

Stars die when they run out of fuel.

MOLLY BLOOM: If a star has a lot of mass, this results in an explosion called a supernova.

UMA: Supernovas create so much pressure and heat they can make elements and throw them into space.

MOLLY BLOOM: And over millions and millions of years, these cycles of supernovae produce the materials that make up our galaxy, our planet, and even us humans.

UMA: So in a way, we're all made of stardust.

MOLLY BLOOM: That's it for this episode of *Brains On.*

UMA: It was produced by Molly Bloom, Ruby Guthrie, Marc Sanchez, Sanden Totten, and Menaka Wilhelm.

MOLLY BLOOM: Our stellar fellow is Anna Goldfield, and our executive producer is Beth Perlman. The executives in charge of APM Studios are Lily Kim, Joanne Griffith, and Alex Shafford. Rachel Greise sound designed this episode. We had engineering help from Johnny Vince Evans. Special thanks to Sophia Gorungatu, Subu Katumore, Tofer Ralph, and Ja Wu.

We also want to give a super duper extra special thanks to our dear friend and colleague Menaka Wilhelm. Menaka is off to other adventures in the world of science. She's now going to share her many talents with the Lawrence Berkeley National Laboratory. Menaka's smarts, humor, sunshine, resilience, and kindness are now baked into the DNA of our show, and we're going to miss her very, very much. Lucky for us there are now 100 episodes of our show that she's helped to make, and her sparkly voice is in many of them.

MENAKA WILHELM: As a crystal.

MOLLY BLOOM: We love you, Menaka.

SPEAKER 1: *Brains On* is a nonprofit public radio program.

MOLLY BLOOM: There are lots of ways you can support the show. You can donate, buy our books, or tell your friends about us.

SPEAKER 2: Head to brainson.org to find the links to donate and order the books.

MOLLY BLOOM: Now, before we go, let's go back to that mystery sound. Here it is again.

[MYSTERY SOUND]

Any new thoughts, Uma?

UMA: Well, I still think it's somebody stapling papers, but maybe that sound in the background is like a fan.

MOLLY BLOOM: So they're stapling papers in front of a fan because it's hard work to staple.

UMA: Yeah.

MOLLY BLOOM: Right? Yeah. You ready for the answer?

UMA: Yeah.

MOLLY BLOOM: Here it is.

VENUS AND MOLLY: Hi, this is Venus and Molly from Maryland. That was the sound of our mom cracking peanuts to feed birds.

UMA: Oh. Yeah.

MOLLY BLOOM: So, yeah, that cracking sound. I can totally see why you think that would be a stapler. It makes a very similar sound, but that was the sound of the shells cracking open. Have you ever cracked open a peanut before?

UMA: Yeah.

MOLLY BLOOM: It's kind of fun.

UMA: Yeah.

[NUTS CRACKING]

MOLLY BLOOM: If you have a mystery sound you want to share with us, you can do that at brainson.org./contact. Everyone who sends a question, idea, mystery sound, drawing, or high five gets added to the Brains honor roll. Here's the most recent group of listeners to be added.

Park from South Korea; Mina from Brooklyn, New York; Miriam from Teaneck, New Jersey; Eliot and Louise from Atlanta; Aurora from London, England; Lila from Halawa, Hawaii; Angelica from Hemet, California; Max and Rachel from Villanova, Pennsylvania; Marin and Emmett from Reno, Nevada; Okule, Emily, Imani, and Leon from Tawny, South Africa; Bentley from Santa Fe, Texas; Anata from Silver Spring, Maryland; Everly from Waterdown, Ontario; Riley from Annandale, Virginia; Zoe from Las Piedras, Puerto Rico; Stella from Boston; Sofia from Michigan; Eli from Moraga, California; Connor from Springwood, Australia; Chloe from Sydney, Australia; Jacinta from Albany, Australia; Rahi from Mercer Island, Washington; Kieran from Eagan, Minnesota; Lucia from San Juan Capistrano, California.

Luke from Australia; Oliver from Kaunas, Lithuania; Kieran and Rohan from Oldsmar, Florida; Annabelle and Caleb from Winchester, Massachusetts; Zoe from Portland, Oregon; Ezra and Lucy from San Jose, California; Neave from St Vincent de Toros, France; Jonah from Northampton, England; Oliver, Avery, and Sunday from Vista, California; Sonia from Bedford, New Hampshire; Jayden from Lake Tahoe, Nevada; Anastasia from Brunswick, Maine; Rafael from Alexandria, Virginia; Jordan from Sunshine Coast, Australia; Zoe from Long Beach, California, Karsiah and Ethan from Watecha, New Zealand.

Celeste from Northfield, Minnesota; Joey from Cheshire, United Kingdom; Ellie from Columbia, Missouri; Tisui from the Northwest Territories, Canada; Aia and Ian from Kansas City, Missouri; Rowan from Wyoming, Minnesota; Finn, Iver, and Olin from Sammamish, Washington; Eli from Irvine, California; Beckett from Calgary, Alberta; Julia from San Diego; Sophie and Levi from Carolina Beach, North Carolina.

Amelia from Chicago; Tyler from Dallas; Jackson from Middletown, Connecticut; Whitman and Jack from Fayetteville, Arkansas; Lilica from Santa Barbara, California; Liv from Palo Alto, California; Caden and Devin from Port Washington, Wisconsin; Madeline and Alexis from North Myrtle Beach, South Carolina; Zach from Canberra, Australia; Franklin from Tasmania, Australia; Sella, Adam and Selma from Jordan; Juliana and Elena from Manassas, Virginia; Vivian from Silvan, North Carolina; RJ from Rockaway Park, New York; and Lila and Iris from Overland Park, Kansas.

[MUSIC PLAYING]

We'll be back soon with more answers to your questions. Thanks for listening.