[MUSIC PLAYING]

ANNA FREBEL: It's a very fundamental question for humanity to ask, where do we come from? And we are, in some sense, A) trying to study that, and B) trying to educate everyone about that.

SARAH HANSEN: Today on Chalk Radio, we're talking star stuff. In this episode, we're going to be exploring stellar archaeology and the origins of, well, everything.

ANNA FREBEL: It all comes from the cosmos, from the stars, and from the supernova explosions.

SARAH HANSEN: Our guest today is associate professor of Physics, Anna Frebel. In a series of short videos created to go with her book *Searching for the Oldest Stars,* she reveals the secrets of stardust and explains the cosmic origins of the elements.

ANNA FREBEL: Hello. My name is Anna Frebel. I'm a physics professor at MIT, but I'm actually an astronomer. So I sit in the Astrophysics division, and I search for the oldest stars in the universe. And it's really cool. And I think we're going to talk a lot more about that.

SARAH HANSEN: It is pretty cool. And what's even cooler is that by the end of this podcast, you'll understand what she does, even if your prior experience with astronomy, like mine, starts and ends with gazing at the stars and saying, wait, is that the Big Dipper? And that's exactly why we wanted to have her on this show. She's an expert science communicator. She conveys complex topics in inspiring and clear ways.

As the title of her book suggests, much of Professor Frebel's work is rooted in learning more about the origins of the elements by studying the oldest stars in the universe. I was curious how old we were talking about.

ANNA FREBEL: We want to figure out exactly how element formation proceeds. And you have to look at different types of objects in the cosmos to figure it out because all the elements are made there. Now, if you take the sun, for example, the sun is about 4.6 billion years old. And the universe is about 13.8 billion years old. So the sun and its content reflects the state of the universe 4.5 or 4.6 billion years ago.

Now, that's pretty cool that we get this kind of information. But it actually is much better for us to look at stars that are much older, that are formed sooner after the Big Bang. And that's why we look at the oldest stars. By studying the composition of these stars, we can then figure out what produced all these elements that we're seeing in the stars.

SARAH HANSEN: This process of looking to the oldest stars for information about the building blocks of the universe is called "stellar archaeology." And it helps us look into the past, way into the past.

ANNA FREBEL: We are archaeologists of sorts. We are really good in piecing together the past because every distant object whose light we're seeing has traveled some time to us. And we are now seeing it as when, for example, a galaxy was in its baby stage, we're seeing that now. So that lets us explore the past.

Now, these stars that we are exploring are in the Milky Way. And that's really our local cosmic neighborhood. The light travel time within our galaxy is thousands of years, perhaps, at least to the stars that we're looking at. So compared to the age of the universe, that's next to nothing.

So we are not looking for stars that are very distant and whose light has traveled to us for literally a gazillion years. We are looking for stars that are truly old and still sitting there. And again, by studying their composition, we can then learn what the universe looked like at the time of their formation soon after the Big Bang.

SARAH HANSEN: You might be wondering how a scientist does this sort of work, this stellar archaeology, digging into the farthest reaches of the universe. You'd have to use some of the best telescopes in the world. And it's definitely not something you could set up in your backyard.

ANNA FREBEL: You have to fly to South America to Chile because most of the big telescopes are located there. Others are located in Hawaii. And while this sounds like a vacation, it's really anything but.

[ANNA FREBEL LAUGHS]

So you usually fly through Miami or Atlanta. And then you have to get to Santiago, to Chile, the capital of Chile. And then you have to fly another hour from there to La Serena.

And then you get picked up by a car, and it drives you 2 and 1/2 hours up into the mountain. And you'll get there, and you see the glistening telescope domes on the horizon waiting for you.

And then it's like a tiny, tiny little village up there. So there are guest rooms for the observers where you'll sleep during the day. So thick curtains are a must. And when also you get there are you'll meet other observers from the other telescopes. You'll have your dinner.

And then you go to the telescope. And then you sit there with lots of monitors. And you work together with a telescope operator. They operate the actual telescope and the dome and make sure that you don't break anything.

[ANNA FREBEL CHUCKLES]

And then the astronomer operates the instrument. So that's basically a giant digital phone camera or a spectrograph. It's like a prism where you split the light into rainbow colors. So you have your buttons to press and decisions to make, and, of course, the whole strategy about what to observe and how to spread things out over the entire night so that you use every single second of telescope time that you have because it's expensive and never enough telescope time.

[ANNA FREBEL LAUGHS]

And then you get tired, but you keep going. And you get even more tired, and you keep going until the sun literally comes up again. And at that point in the sunrise, you just go back to bed and then sleep as much as you can during the day. And then history repeats itself. But if the weather is bad and, let's say, there are clouds, or it rains, or it snows, or something else, then tough luck. You go home empty-handed.

SARAH HANSEN: Now, when Professor Frebel is at the telescope down in Chile, she's getting a very different perspective than when she's back here in Cambridge, Massachusetts because the universe you can visualize is different depending on where you're observing from.

ANNA FREBEL: We have a different night sky in the Northern and the Southern hemisphere. And that's because of our orientation in the galaxy. We live in a spiral galaxy. And so what we see as the "Milky Way," in quotes, on the night sky is actually the next door spiral arm. And so that's why we have a band.

Now in the Northern hemisphere, we're looking at the spiral arm that's behind us. So we're looking outside of the galaxy. So we're looking out. In the Southern hemisphere, we're looking in. And so it's really bright and shiny.

And that backlights the spiral arm. And so when you're in the Southern hemisphere, you see a beautiful bright band over the sky, much unlike what we have in the Northern hemisphere. It's truly remarkable how bright this can be.

So there's time during a single exposure to sneak out and look at the sky because I'm still a person. I'm not just a scientist. And I do like looking at the sky.

And so I have been just walking outside with my flashlight under the Milky Way. And you can actually switch off your flashlight there and just walk in the light of the Milky Way, no moon, just starlight. You can totally find your way around.

SARAH HANSEN: I was curious to learn more about how Professor Frebel went from stargazing with the rest of us to stellar archaeology. What made her want to dig so much deeper into our cosmos?

ANNA FREBEL: It's just always been with me. Ever since I was little, I knew I wanted to work with stars. And I knew it wasn't planets, and it wasn't galaxies, it was stars.

And I can really only describe what draws me to this and always has is the analogy to why is blue your favorite color? Why is it not red? It's just more like a feeling.

And it really hit me when I learned about old stars. I did not know about old stars specifically until I was 22. But in Australia, I first encountered old stars, and I knew that that's it for the rest of my life.

[ANNA FREBEL LAUGHS]

SARAH HANSEN: As I shared earlier, Professor Frebel is the author of the book *Searching for the Oldest Stars,* which makes this extremely complex topic accessible to anyone still retaining some of that childlike wonder and curiosity about the world around, or rather above, all of us.

ANNA FREBEL: These times really speak for themselves. People need to have more scientific literacy. And I think the forgotten point is that so much wonder comes along with it. Information is power, but it's also wonder.

And I think it's really, really important as a scientist to make your work accessible. You don't need a bachelor's in science to understand that your body is made of different things.

And we always ask the question, where does stuff come from? Where does the money in my wallet come from? That's what my five-year-old is asking now. So, yeah, from my bank account. But the story is, obviously, a lot bigger.

And science is exactly the same thing. I mean, I could talk to him about the economy and the stock market and make it really, really complicated. But in the end is I have a job, and it pays, and that's the basic idea.

And actually coming back to the stellar archaeology concept, I think everyone should really know what their ancestry is like. And we are doing the exact same thing in the cosmos. We're looking at stellar generations and what came before. And it's a very fundamental question for humanity to ask, where do we come from?

SARAH HANSEN: Part of Professor Frebel's approach involves pulling back the curtain on what astrophysicists actually do on a day-to-day basis. And this is something she feels pretty passionate about.

ANNA FREBEL: The Nobel Prize was won for this and this discovery. That's cool. That's very impressive. But is that really the interesting bit? I think for many people it's actually much more interesting to hear the journey about what went all wrong on that path to success. We like to just take the success in the end and throw away the 99 other percent, but that's not what life and reality is like. As I said, we go to the telescope and it's cloudy.

But once I found something, I made a big discovery, then everyone literally forgets how many struggles you had getting there. It's great to have success, but most of life is-- it's not success. It's hard work, and it's facing the struggles. And I think reminding people that even when you do have success there's really much, much more to the story.

SARAH HANSEN: Professor Frebel's videos on MIT OpenCourseWare are meant for anyone to learn from regardless of previous physics or astronomy knowledge.

ANNA FREBEL: It's really for anyone. And the book is written in the same way. If you don't like a chapter, you can just go to the next chapter. You could even read the chapters backwards. It's all set up so it's completely interchangeable and flexible.

I think that children age 10 or 15 could probably start watching this because, again, it's about the big questions. If you don't understand a sentence or the detail, man, don't worry about it.

You want to wonder and be amazed by something, it's perfectly fine not to understand the details because it's not the details that make you amazed. It's catching a glimpse of something bigger where you develop the desire to understand more. And once you want to understand more, why, details a drop in the ocean.

SARAH HANSEN: In parting I wanted to go from looking to the past to looking to the future. What exciting things are scientists doing to pave the way for more discovery and to inspire joy and wonder for generations to come?

ANNA FREBEL: What I foresee in the next 5 to 10 years is that this combination of knowing more about how the elements are all created and on what timescales, finding, of course, additional old stars and at all ages, using their motions on the sky, and then combining that with large simulations for the formation of the Milky Way. And so I think there's going to be a lot of work into really figuring out all the puzzle pieces that put together make up the Milky Way.

And we've figured out a few big ones. But there are still lots of little details that we need to figure out. And I think that that's going to be the big thing. So the Milky Way in the bigger view, in a more holistic view, that's going to be the focus in the next 10 years.

SARAH HANSEN: Ultimately with the help of educators like Professor Frebel, astrophysics can be a way to become more interested in the world, an avenue for understanding our place in a much, much larger scheme of things.

If you are ready to learn more about the cosmic origin of the elements or have students who would be inspired by stellar archaeology, you can find Professor Frebel's videos on our MIT OpenCourseWare website. Our resources are always free and remixable. So they're perfect for use in your own teaching.

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Thank you for listening. I'm Sarah Hansen from MIT OpenCourseWare signing off from under the night skies over Cambridge, Massachusetts

LITTLE GIRL: (IN BOSTON ACCENT) Ma, pahk the cah.