Dave Eicher: Welcome to the Superstars of Astronomy podcast from *Astronomy* magazine. I'm Dave Eicher, editor-in-chief of *Astronomy*. Each month I'll share the thoughts and research of the world's greatest astronomers, astrophysicists, cosmologists and planetary scientists with you in these hour-long chats. Superstars of Astronomy is brought to you by Celestron. From your first telescope to precision observatory-grade instruments, Celestron has the perfect telescope to suit your experience level and budget. You can find out more at www.celestron.com.

And I'm delighted today to have as our eighth guest on this show a distinguished astronomer, Seth Shostak. Seth is senior astronomer at the SETI Institute and director at Center for SETI Research. He also heads the International Academy of Astronautics SETI permanent committee. Seth hosts the Big Picture Science radio show, which features a broad range of topics in science.

He's a very well-known and entertaining speaker and has written numerous articles on science, including longtime contributions to *Astronomy*. You can find Big Picture Science at www.bigpicturescience.org. And so without further ado, it's really a pleasure to welcome someone who I've known for many, many years and admired, Seth Shostak. Seth, thanks for being with us today.

Seth Shostak: Well it's my pleasure, David. It absolutely is my pleasure. *[Laughs]*

Dave Eicher: Thank you, thank you. And let's just talk. You had a long and very distinguished and exciting career. Let's talk about how did — you got interested in astronomy at a very early age, did you not?

Seth Shostak: Well I did. I can remember being intrigued by the stars when I was still being carried around by my parents because they would occasionally do that at night. *[Laughs]* So I could see these things, and of course when you're a kid, you don't really quite understand all the ramifications of these lights in the sky, but I was interested in them. But I got seriously interested in astronomy or more seriously when I was 8 and I tripped across a diagram of planets in the back of an atlas actually. I was very interested in maps at a young age. So that I think started it all, age 8, yep.

Dave Eicher: That's very early, and you really pursued that interest, and then you ended up going and studying physics at Princeton, is that correct?

Seth Shostak: I did. Yes, I did. But even there, although I was studying physics, you know, you had to do what was called a senior thesis. This was the triumph of packaging over content I think because to call it a thesis was perhaps a little bit strained, but even that *[laughs]* the basic idea was in fact to measure the diameter of a star in the sky. So that, you know, it was actually more astronomy than physics in some sense.

Dave Eicher: Very good. And of course physics is the gateway to astronomy, as we know it, especially as an undergrad. And then you went to study astrophysics to work on your Ph.D., which you completed at Caltech. And what did you — when you went into grad school, how did your interest develop and bloom?

Seth Shostak: I actually entered grad school at Caltech in the physics department, but I think it was the first week I was there I wandered over to the astronomy department, and they had all these wonderful drawings on the walls of the construction of the 200-inch telescope at Mount Palomar. And at the time, you know, Mount Palomar was still the largest optical telescope in the world. So I got interested, and then I switched to the astronomy department, which they seemed to think was okay. And so I looked around, you know, after I passed all the first- and second-year courses in physics and astronomy that were requisite for doing a Ph.D., I looked around for a thesis topic.

And, you know, that meant spending, I don't know, a week in the library just trying to figure out what were the interesting problems in astronomy at that time and, you know, not just interesting to the astronomical community, but also to me and also, you know, projects that might have some support there at the school where I could actually do a thesis. And I decided, you know, I was always interested in electronics too, so radio astronomy seemed to be it, and at that time it was still fairly early in the days of radio astronomy. In those days you could point a radio telescope up at the sky for a couple hours and find something that nobody had ever seen before. It was all, you know, virgin territory *[laughs]* —

Dave Eicher: There wasn't —

Seth Shostak: — as Richard Branson would say — yeah.

Dave Eicher: — a lot known about the radio universe at that time we — and it wasn't all that long ago. It's quite amazing.

Dave Eicher: Yeah, well it *[laughs]* wasn't all that long ago cosmologically speaking.

[Laughter]

But it seems long ago to me. I — in any case — so you know, I — we had this — there was a radio telescope array Caltech had, and still has by the way, up in the Owens Valley behind the Sierra Nevada Mountains here in lovely, glamorous California. And we were able to push those babies around and spend months observing and make maps of galaxies, which was sort of interesting in the radio, but not only could we, you know, map them out in hydrogen gas, we could also tell how fast the galaxy was spinning around. And we did that for a half-dozen galaxies, and I was nonplussed to find that they all spun too fast, they all spun too fast in their outer regions. This was in the last 1960s, and we were — you know, we're the first to show that galaxies actually had what are called flat rotation curves, that they were spinning too fast and that was due to something we now call dark matter. So —

Dave Eicher: This is a big, big deal at the time.

Seth Shostak: Well it wasn't such a big deal at the time, but shortly thereafter, about five years later actually, some optical astronomers got into the game, and they found flat rotation curves, and then the astronomy community began to take notice. But we had found that already in the 1960s.

Dave Eicher: That's amazing. And so you had a brushing encounter with dark matter there but also got involved at NRAO [National Radio Astronomy Observatory], you were working in West Virginia, and you acted as a research associate at the Kapteyn Institute in the Netherlands as well. How did all of that come about, your various affiliations doing radio astronomy?

Seth Shostak: Well I would like to say, Dave, that it all came about because of my talents and assiduous efforts, but you know, I gotta be honest with you *[laughs]*, as Clint Eastwood said in a movie once, "A guy's gotta know his limitations."

Dave Eicher: *[Laughs]*

Seth Shostak: And so most of these jobs were the result of sort of cosmic accidents where I knew somebody at the observatory and they knew I'd completed my degree, and they'd say, "You want a job here for two years?" That kind of thing. Or in the case of the Kapteyn Astronomical Institute in the Netherlands, they had just built an antenna array, a radio telescope, there at a place called

Westerbork and it was at the time the biggest such instrument in the world. This was something like 10 or 15 years before the VLA [Very Large Array] was going to get underway in New Mexico. So at the time, this was the biggest and they needed radio astronomers who knew how to run this baby and could use it for something interesting.

And, you know, I was sitting at my desk in Philadelphia, I'd had another job at that point, and I got a phone call from the — if you will — the dean of the astronomy department there who was a guy I knew. And he said, "You interested in a job here for two years?" So, you know, that's how it happened, and you could say well, you know, that's all kind of inside job stuff, but ask anybody how they got their job, and I think you'll find that eight out of 10 got their job because somebody knew them.

Dave Eicher: Sure, sure. And it was a temporary stop, if you will, but you really enjoyed the Netherlands though, didn't you?

Seth Shostak: I did. Yeah, I did. You know, the Netherlands it — this is a fact that's not appreciated by many people and least of all by the Dutch themselves, but the Netherlands consistently ranks at number two in the world in terms of astronomy research. You might wonder about that. Number one is the United States, which I'm pleased to note. I assume this is still true, by the way. This — these data are a little bit old, but the Netherlands was number two, and, you know, you think of one of the biggest exports of Holland, people think like cheese and beer and, you know, stuff like that.

Okay, that's all true, but it's also astronomers, you know? The — if you look at the directors of observatories or astronomy departments around the world, a lot of them are Dutch. They export a lot of astronomers. And I think that the reason that the Dutch are so big in astronomy is not because they have big mountains *[laughs]* where they could put telescopes on top. They don't. It's not that the weather's always clear because it's not. But it's because they were a seafaring nation, heavily depending on sailing ships and they needed to navigate. So they set up astronomy organizations very early.

Dave Eicher: Very nice. And you also worked on computer simulations and a fair amount of software engineering in this period in your career as well. Was that all astronomical, or did it sort of tease outside the focus of astronomy?

Seth Shostak: Yeah, well in the beginning I was writing all this image-processing software because of our study of galaxies actually. It was essential to do that. In those days, the astronomers could still write the software. *[Laughs]* I don't know if they can still do it today, but they could then, and we did, and, you know, but I was always interested in films and stuff like that, so the Dutch television people called me up one day and they said, "Look, we're doing an astronomy show, and we need to show the expansion of the universe, the Hubble expansion." And they said, "You know, can you film that for us? We'll pay you a little bit of money."

It was a very little bit of money. And so, you know, I got out my 16-milimeter camera, and I got the neighborhood kid in, and I had her blow up some balloons, and I — you know, I penciled or rather used a magic marker to put, you know, little spiral galaxies on the balloon. I thought that would do it. It did not do it. It was *[laughs]* really cheesy looking, and it really didn't convey the idea. So I went down to the computing center one evening, and I just — it took about a half an hour to write a little program that would make the expanding universe with spinning spiral galaxies on the outside on the computer, frame by frame. And I put my 16-milimeter movie camera in front of that, spent four hours clicking the shutter once every 30 seconds, and what came back was such an impressive piece of film to me — I'm easily impressed — that we started a company that did computer animation. And for many years we were doing computer animation for television and things like that.

Dave Eicher: That's exciting. And then of course, as everyone knows, your specialty then really came to be astrobiology. And how did you get driven? Was it — it was the radio astronomy that drove you toward thinking about life in the universe?

Seth Shostak: Well I don't think so. I mean —

Dave Eicher: OK.

Seth Shostak: — it certainly drove toward doing it as that connection is pretty good, but you know, I think most people are interested in life in the universe. And to me it — I think that's a hardwired interest. I mean we're interested in certain things because there's survival value being interested in them. For example, you're interested in finding a mate. Well that has obvious survival value. But you might also be interested in dinosaurs or anything else with big teeth for obvious reasons, right? So go into any sixth grade classroom, and ask the kids, "How many of you are interested in dinosaurs?" They all raise their hands. Tune in to Animal Planet. Is it going to be a story about, I don't know, snakes, lions, crocodiles, or is it going to be a story about gerbils and ground squirrels. It's going to be about things with big teeth.

Dave Eicher: Sure.

Seth Shostak: You're more interested in things with big teeth. You — there's some reason to be interested. And I think the same of true of aliens, I really do. I think that you're interested in other beings that might be competitors, you know, that might be dangerous, whatever. So again, you go into that sixth grade classroom, and you ask the kids, "How many of you are interested in aliens, or how many of you think there are aliens out there?" It doesn't really matter.

All the hands will go up again. So I was interested just like all those other kids, and I had seen a lot of bad movies about aliens, so I was doubly interested. When, at some point when I was a grad student, it dawned on me that radio telescopes could be used not only to study galaxies but maybe also to pick up E.T. Well that was a very exciting idea, and I didn't do much about it for a while, but eventually I started doing experiments there, and I ended up here at the SETI Institute.

Dave Eicher: And the perfect place for you. And here's the question — and I'm cheating a little bit here because you were kind enough to read my chapter about the meaning of life in the book that's coming out later this year that I wrote, so I had very good training in terms of adjusting exactly what ought to be talked about in terms of this. But here's a question that has to be asked first, that everyone wants to hear you talk about immediately. You would be the one likely, if we did detect extraterrestrial life, a civilization through SETI, you would know first probably on the planet. How would such a detection work? Can you work us through what's the mechanism, what is the current status of the radio telescopes that are in play? How would that work if you found out that there was another civilization in the universe?

Seth Shostak: Well, to begin with, we're not the only SETI experiment on the planet, although there aren't many. There's a very good set of experiments being run by the University of California at Berkley, so they're about 50 miles away from where I'm sitting here. But our experiments use the Allen Telescope Array. Many people will have heard about that, and if not, look it up: Allen Telescope

Array. And that's a set of 42 antennas about 350 miles north of where I am, 300 miles north of San Francisco.

We use those about 12 hours a day to, you know, look at nearby stars mostly or sometimes the center of the galaxy and so forth, trying to pick up a signal, a signal that would be clearly extraterrestrial. Not a signal due to the radars down at the airport, not a signal due to, you know, telecommunication satellites wheeling overhead, none of that. A narrowband signal is a signal at one spot on the dial that moves at the sidereal rate of the stars, moves across the sky just the way the stars and whatever do. So that's what we look for. Now what happens if we pick up a signal? Well, first off, we pick up signals all the time.

[Laughter]

I mean every few seconds you pick up a signal, right? We've got these big antennas, we've got receivers that are listening to 30 million channels at once. Of course you pick up signals, and nobody gets terribly excited about that. In fact, nobody even knows about it, only the computers. But they go through and they make some very simple tests that, you know, can rule out almost all of them right away as being terrestrially produced, not E.T. If they find something that looks like it might be the real deal, then what happens?

Well we still don't know about it because the computers automatically, you know, start scanning around wherever in the sky they think the signal's coming from to make sure it's really coming from one spot on the sky and isn't just interference from over the horizon. All that's automated. Now at some point — and this happens very, very infrequently — at some point a signal will pass all these automated tests and then of course the software lets you know, and now what happens? Well what happens is you go back and manually you do all the tests you can think of. And you might spend a day doing that. If it still looks good, and this has happened not often — once that I can think of — if it still looks good, then you would call up somebody at another radio observatory, and you said, "Look, Bob, you know, sorry to break into your observing program."

[Laughter]

You know, that's what you're going to be doing, and say, "Look, would you mind, you know, looking in this patch of sky at this range of frequency? I'm not going to tell you everything because I want an independent confirmation. See if you can find it." Because you wouldn't believe it if you were the only one to find it. So that's what you would do. And if they found it too, at this point you could say, all right, call the press conference or maybe call the White House depending on how you feel about these things. But, you know, that's kind of naïve because in our experience what really happens is because there's no policy of secrecy, the press already has known about this signal for days, *[laughs]* and they've already been calling you.

Dave Eicher: Sure.

Seth Shostak: They've already written stories, so that's what really happens.

Dave Eicher: Now let's talk — is it possible to character — now obviously, we're — the computers are listening for a not — a "non-natural" and ideally repeating signal. It — is it possible — can you characterize what kind of a signal — what are we talking about possibly the computer "hearing"? Is it possible to describe that or is it so close to a lot of natural radio signals that it's really difficult to sort of articulate what that would consistent of in your mind?

Seth Shostak: Well, yeah. That's actually a good question and — because people always assume, well, we're looking for a — you know, special patterns in the signal. You know, here's the value of pi or the Fibonacci series or prime numbers or whatever. I mean they use a lot of that in the movies.

Dave Eicher: Yes.

Seth Shostak: But that's not the way it works, because in the first instance you're just trying to find out that there's a signal there. So you're just looking for a lot of radio energy over a very narrow part of the spectrum, over a very narrow range of frequencies, right? I mean it's kind of like a laser pointer. You know, laser pointers, they're not very powerful. They're measured in tens of milliwatts, right?

It's a hundredth of a watt or something, but they look very bright because they put all that energy into a very narrow range of wavelengths, in maybe red or green or whatever it is. So by doing that, you make the signal much brighter for the same amount of energy. So we figure if the aliens are just trying to at least get our attention, they will put a lot of energy into a narrow part of the spectrum so we at least see that there's a transmitter up there. And if you find that, of course, you go back and you build, you know, completely different kind of equipment that's much more expensive but the kind of equipment that might find whatever message might be in that. Presumably there'd be a message, but who knows. But that's what you look for. You look for that, if you will, equivalent of the laser beam. A lot of energy and a narrow range of frequencies there.

Dave Eicher: Excellent. And let's step back and talk about Enrico Fermi for just a moment. The Fermi Paradox, let's just throw this question out there. We've got — we believe at least 10,000 billion, billion stars in the universe and maybe many, many more because we're talking about the visible universe, where is it? Now life must be and civilizations must be out there in plentiful numbers, but we haven't found them yet. Can you describe why that is?

Seth Shostak: Well I can't explain why that is except to suggest *[laughs]* some things. I mean obviously if I knew, you know, there would — answer to all these questions. But it is true that we haven't found anything yet. Now when people say, "Yeah, you guys haven't found anything, they're probably not out there." Well, that's not right.

Because yes, we haven't found anything, that is right, but on the other hand we've only looked at a few thousand star systems carefully. And if you think about it, you know, there are hundreds of billions of star systems just in our galaxy, and as you pointed out, there are 10^{22} star systems in the visible universe, so, you know, the fact that we've looked at a few thousand means that we *[laughs]* haven't even scratched the surface. We've sort of blown on it a little bit. So the — you know, I think that's the reason we haven't found anything. But the Fermi Paradox is slightly different.

What Enrico Fermi noted in 1950 or at least is reputed to have noted, and this may be all an apocryphal story, but nobody seems to know. There's some people who claim they were witnesses and others, I don't know. But he said, "Look, you know, it only takes a few tens of millions of years to colonize a whole galaxy," right? That's kind of a back-of-the-envelope calculation but —.

Dave Eicher: It sure is. Yeah.

Seth Shostak: Yeah, it depends on speeds of rockets and all that, but you know, within factors of 2 or 10, whatever. So if it only takes a few tens of billions of years — sorry, tens of millions of years — to colonize the galaxy, and the galaxy is 10 billion years old or more, then you know, there's been a thousand times *[laughs]* as much time around for — that is — than is necessary, if you will, to colonize the galaxy. Now I think the way to look at that is this: When the Spaniards discovered the Americas, you know, in the late 1400s, early 1500s, it only took them 30 years to have colonies all up and down the coasts. It went really quickly once they got started. So Fermi's argument is something similar.

He says if anybody wants to colonize a galaxy, they can do it really quickly compared to the age of the galaxy. And so if there really are lots of societies out there and always have been, then *[laughs]*, you know, you should see outposts everywhere. Mos Eisley over here and whatever, and Tatooine over there. I mean there ought to be, you know, settlements everywhere.

We should see evidence of extraterrestrials everywhere, and we don't. so he thought that was significant or may be significant. I think what he really thought was that that proves that interstellar travel is not a — is a nonstarter, but whatever. That's known as the Fermi Paradox, and it says we don't see the aliens here, so consequently, there are no aliens anywhere. I think that's a pretty bold statement from fairly weak evidence myself.

Dave Eicher: That's a pretty bold statement indeed. And one thing that relates to this that no one, even sophisticated astronomy enthusiasts — now obviously it's different for professional astronomers — but even fairly well-read, astute, highly intelligent, very discerning people, they — it's very difficult for people to comprehend and to appreciate the cosmic distance scale. It is a really, really large place, even the nearest stars to us in the Milky Way.

Seth Shostak: That's true. And actually, that's alluded to occasionally when people will say, "Well, if you guys pick up a signal, it might be millions of years old and then that society that sent the signal might be long gone, self destructed." Well to begin with, it doesn't have to be millions of years old. I mean the nearest star is 4.5 light-years away and within a couple hundred light-years you have a million star systems, right? So if one in a million star systems has some sort of society with a radio transmitter, they might only be 200 or 300 light-years away.

So that means the message is 200 or 300 years old, and maybe they've self-destructed in the *[laughs]* last couple of centuries, maybe, but maybe not. I mean that's a pretty short period of time. And what the heck, even if they have self-destructed, I mean I'm — you know, you might still read Homer, you know, *The Iliad* and *the Odyssey*, and you know, he's gone for 2,000 years. So, so what? It's still interesting. Well it's sort of interesting. Anyhow, that's a —

[Laughter]

So I don't — I mean obviously it makes it hard if you want to get into conversation, you know, that's very tedious, but if all you want to do is say, wow, we found somebody and maybe we can even learn something from their transmission, then the fact that it's a little bit old doesn't bother me terribly much.

Dave Eicher: No, it doesn't at all, but it really severely restricts the idea of traveling physically between star systems. Radiation is one thing, but as you said, interstellar travel that's really realistically a very tough go, isn't it?

Seth Shostak: Yeah, well it seems to be. I have to say that we've had a talk here at the SETI Institute by a gentleman by the name of John Rather, a very creative guy. And he says, "You know, it's possible to throw hardware at the nearby stars, and you can do that with essential 3-D printers that make more 3-D printers that are bigger so then they can make even bigger stuff, including bigger 3-D printers that make yet bigger stuff." You know, this sort of bottom-up approach to engineering stuff that you could send into space. You send a really small 3-D printer, if you will, into space on a rocket that — you know, on a spacecraft that doesn't weigh as much as a bowling ball.

Weighs as much as maybe a — you know, a softball or something like that. Maybe a pound, 2 pounds, something like that because if it's very lightweight, then you can think of ways of speeding it up to maybe a few percent the speed of light. That's possible with technologies that, you know, we could actually build if you really wanted to. And that means that you could get to Alpha Centauri, for example, in what, 120, 150 years. OK, now that's sort of a long time, but it isn't — you know, it's not thousands of years, it's not millions of years. It's 120 years.

Dave Eicher: Yeah.

Seth Shostak: And so you send all this stuff there, and it builds machinery. You know, it does what I just said, sort of one machine builds a slightly bigger machine which builds a slightly bigger machine, and eventually, you know, then you feed it an ovum, a human ovum, or you just send it the DNA of a human and, you know, you got all this machinery there and maybe you can do something with it.

Maybe produce a baby. You know, I don't know, a bit farfetched, but that kind of bottom-up approach to traveling to the stars has a certain appeal. And is it impossible? It doesn't seem to violate any laws of physics, so you know, who knows?

Dave Eicher: So difficult but maybe not impossible. And what about also sending nanobots? Really tiny craft?

Seth Shostak: Yeah, exactly.

Dave Eicher: Perhaps, yeah.

Seth Shostak: The smaller they are, you know, obviously the less energy's that's required. I, on the other hand, you know they *[laughs]* can't be so small that the, you know, interstellar dust wipes them out.

Dave Eicher: Sure.

Seth Shostak: Or — and they can't be so fragile that cosmic rays and, you know, other kinds of radiation in space wipe them out. So, you know, you might need some sort of box for them, and the box may be the heaviest part of the package.

Dave Eicher: Yes, indeed. Now another question everyone wants to know from you is you've worked with a couple of very special people at the SETI — many special people — but a couple of extremely famous folks with Frank Drake and with Jill Tartar, of course. What has it been like to know them and to work with them over the years?

[Laughter]

Seth Shostak: Well, Dave, the first thing you find out is that people are in the end people, so there's that. But no, it's actually — it's a privilege, to be honest. I mean in general I feel like it's a privilege to be here, and it isn't the boss who's twisting my arm here asking me to say that. That isn't true. It really is because after all, you know, we're wrestling with a really big question here, and most jobs don't give you that opportunity, so that's nice. And, you know, these people are interested in ideas and that sort of thing, and that's also very special.

Frank Drake is, you know, one of my personal heroes. He's one of the world's last nice guys, I gotta say that. And beyond that, he's very soft spoken, but whenever he talks you really ought to listen because Frank is a very clever guy. And, you know, as you pointed out, both he and Jill are very well known. You go anywhere, and the people will know about them. I actually asked Frank Drake years ago, I said, "Frank, you're one of the most famous people I know. You know, have you gotten any benefit from all that notoriety?"

[Laughter]

So, you know, he thought about it for a second. He said, "Well," he said, "years ago I was doing some work on my house, and I ordered some lumber from the Santa Cruz lumber yard here, and the guy came up and I gave him the check. And he looked at the check, and he said, 'Frank Drake. Are you the Frank Drake?'" And Frank admitted that he was, and so the guy gave him free delivery.

Dave Eicher: Wow. There you go, huh?

Seth Shostak: You see, fame has its rewards. That's all I can say.

Dave Eicher: Fantastic. And of course Jill was the inspiration of course for the Ellie Arroway character in the film version of *Contact*.

Seth Shostak: Yes —

Dave Eicher: A very famous name.

Seth Shostak: Well there's several people who have made that claim, but I think that Jill's claim is by far the best. And — but Jill herself is very — I mean she's kind of modest. She's very careful not to actually say that herself. She will simply say that, well, it's true that I do SETI, and it's true that my father died when I was young and so forth, so she'll point out some of these parallels, and you draw the conclusion yourself. She would be — would not be so brazen as to suggest it herself.

Dave Eicher: Yeah. Now let's talk a little bit for those who don't know, could you characterize the history and the importance of the Drake Equation —

Seth Shostak: Sure.

Dave Eicher: — and what that did to SETI and astrobiology?

Seth Shostak: Yeah. I've heard it said that the Drake Equation is the second most famous equation in all of science, the first being $E=mc^2$.

Dave Eicher: Sure.

Seth Shostak: I don't know. Maybe that's it, but I always figured the Bernoulli equation was — anyhow. So Frank did the first SETI experiment, modern SETI experiment, in 1960. It was called Project Ozma, and it was done using a small antenna at the National Radio Astronomy Observatory in West Virginia. Anyhow, that generated a lot of interest, and so a year after he did that experiment he had a small conference about SETI.

About a dozen people showed up. These were not, you know, just people off the street. One of them won a Nobel Prize that was announced as he was at this meeting. *[Laughs]* You know, these are pretty interesting folk. But in any case, Frank needed an agenda for the meeting, and so he came up with this equation, which just tries to estimate how many societies are out there blasting away radio waves that are going through our bodies as we sit here and talk, and that's become known as the Drake Equation.

It's a very simple equation. It's just a bunch of terms strung together. But it has become, you know, very, very well known even though there is no solution to this equation; we don't know many of the parameters, but it's a way of organizing, you know, what we need to know. It's great, and it appears I would say in 100 percent of all *[laughs]* astronomy textbooks. It's that famous.

Dave Eicher: Absolutely. And has really been the basis for a lot of what grew out of that era in following, in the '70s and '80s, in terms of SETI. Now you've got probably one of the most exciting and interesting jobs in astronomy doing what you're doing. So can you tell us what is a day in the life of Seth like and what is the current sort of state of the union of the SETI Institute and then what's going on there and funding and the telescopes, plans for the future? Can the listeners help and get engaged with the institute? All those kinds of things.

Dave Eicher: Yeah. People frequently tell me — you're actually the second — maybe the third person today, Dave, to tell me that I have one of the most, you know, exciting jobs in the world, and that's because they don't have my job.

[Laughter]

But, OK. Having just said that, having this job is a privilege, I probably shouldn't belittle that remark too much, but it is true. But if you ask me what do I do day to day, because people will ask that, "So what's your day like? I mean you get to the office, put on a pair of earphones, and hope to hear ET.

Dave Eicher: *[Laughs]*

Seth Shostak: Now this is not what I do. My day job consists of answering email. That's what I think is the majority part of it. I do a lot of writing, a lot of writing, and of course speaking and things like that. So a lot of outreach. We have the radio show, Big Picture Science, all of that. But in terms of SETI, the most important things now are very mundane things like finding the money to continue to do it because SETI is, you know, it's an unfunded activity.

It isn't — it's not government funded, there are no tax dollars going to our SETI project, and so we rely on contributions. So, you know, that's for me it has to be job number one is to try and find financial resources so we can keep the team going. Now that's — OK, most listeners are not terribly interested to hear about money. They want to know about, yeah, but what experiments are you doing?

So let me just say something about that. And we have typically looked at a whole bunch of nearby stars. In the past, they were stars kind of like the sun, figuring that Sun-like stars were the ones that were most likely to have, if you will, Earth-like planets. And, you know, that's still not a terrible assumption, but my personal predilections these days are to go for red dwarf stars. I think that those might be where E.T. is hanging out. In fact, about a year or two ago I wrote an article for *Astronomy* magazine —

Dave Eicher: Yes, indeed.

Seth Shostak: — on red dwarfs. And, you know, red dwarfs have some advantages. To begin with, three-quarters of all stars are red dwarfs. So, you know, if you can only — if you only have enough telescope time to look at, I don't know, you know, 10,000, 20,000 star systems, if you pick red dwarfs, on average they're going to be a lot closer than if you pick stars like the Sun because there are many more of them. It's like, I don't know, you go on campus in an all-girls school — or maybe not an all-girls school but a school where nine out of 10 students are girls — then the nearest girl's going to be a lot closer than the nearest guy.

It's just a matter of the, you know, relative frequency of these things. So by looking at red dwarf stars you're looking at stars that are on average are closer. That would have some advantage for us because the signals could be strong enough to detect, they would be stronger. But the other thing is that red dwarf stars, as you know, last for at least 100 billion years before they burn out, so every red dwarf star ever born since the Big Bang is still out there shining away. You know, they're still kids really. And that means on average, if you look at a whole bunch of red dwarf stars, on average they're billions of years older than if you looked at Sun-like stars. So all that sounds good to me because older might be better. In general, it's not, but in this case it might be *[laughs]* because —

Dave Eicher: It might be, yes.

Seth Shostak: Yeah, you know, because it's had more time to cook up something interesting. So we're going to do that. We're going to look at a lot of red dwarfs. If we can get the money to do that experiment, that would be a very interesting one. But there are many other things. You could — with new technical developments, you could increase the speed of SETI that we do, you could increase that speed by a factor of 10, even 100, just by buying some more electronics, writing some software.

You can do that with technology that you could, you know, put together yourself in a couple years. So it's — that's a money issue, that's a money issue. But the speed of the search could be greatly expanded, so I look forward to that kind of thing. One more thing. This is a much too long answer. But one other thing is that we're also trying to do some optical SETI. We've done that in the past, where you look for flashing laser beams from Klingons or whoever, and try and do it by looking at as much of the sky as possible because if you just look at one star at a time, you know, you might look at the right stars but at the wrong time, so —

Dave Eicher: You've gotta be in the right place and the right time for that.

Seth Shostak: Exactly, yeah.

Dave Eicher: Yes. And for those who don't know, the SETI Institute, it's a large institution. It employs a lot of people.

Seth Shostak: Well, yes it does. Well *[laughs]* I don't want to — not compared to, you know, Google, which is down the street here.

Dave Eicher: Or NASA, no, but relatively speaking, it's a fairly sizeable group.

Seth Shostak: It is. There's like 130, 140 people on the employee list. But I should point out, because many people don't know this, that the majority of the research done in the halls around where I'm speaking to you from are in the field of what's called astrobiology, and they're interested in, for example, the history of water on Mars or could there be life on some of the moons of Jupiter or Saturn? We've all heard of, you know, Europa and Callisto and Ganymede, all of which may have huge oceans, but also Enceladus around Saturn and Titan. It has lakes; they're not water, but they're lakes, liquids. So these are all places where you might find some sort of bacterial kind of life. So they work on that, and that's the overwhelming majority of the scientists here. The number of people in the SETI group is four or five, that's it, that's it.

Dave Eicher: Wow.

Seth Shostak: It's very small.

Dave Eicher: That's really astonishing, wow. And let's talk briefly about how did — the radio show is so interesting and so well done, Big Picture Science. How did that get going?

Dave Eicher: Well *[laughs]* that's sort of an amusing story because there — Jill Tartar was giving a talk down in San Diego, I don't know, a dozen years ago, and she mentioned during her talk that, well, her problem was money. That tune hasn't changed much. That, you know, money was a big impediment. And one of the guys in the audience at that public lecture was a local radio DJ, and he thought — he looked around and he said, "You know, our station gets more people coming out for a car wash than are in this audience." And so he approached the institute and said you guys ought to have a radio show and you'll get a lot more people interested and maybe more money, and so forth and so on.

And the institute said, "OK, Seth, well that's kind of your bailiwick." So this thing started and *[laughs]* it was — it — I look back on those early shows, and I kind of wince, and I could tell you why, but you know, that eventually became the show we have now, Big Picture Science. And after having done these for a while, you know, things like production techniques and, you know, what sort of thing works with audience and so forth, get sort of hammered out. We don't restrict ourselves to SETI. In the early days, it was largely SETI Institute oriented, but that just makes it a commercial.

So we handle all science and technology, pretty much all science. And we have three, four, five guests every week. We usually have skits and other humorous stuff to make sure it stays interesting. The show's on more than 100 stations now, and of course it's podcast too. So that's something that keeps me busy, you know, a little bit of each week. And I have some help on that, and it's fun because it can be creative.

Dave Eicher: That's fantastic. And how can listeners get involved with the institute and support your programs? They — probably the first step is to go to seti.org, I would imagine.

Seth Shostak: Yeah. Yep, yep. You can always do that. If they're interested in the radio show directly, they can just go to bigpicturescience.org, but of course the radio shows are also on the seti.org site so it's easy, it's easy squeezy.

Dave Eicher: Excellent. Well this is one of the great things that all astronomy enthusiasts should be supporting and should be interested in, just like preserving the night sky and fighting light pollution and a few other things that everyone is interested in and wants to support and wants to see move forward. And then we're of course very excited about that detection. Now let's get maybe a little bit more speculative and personal with some of these things. Let's talk about the likelihood of life in the universe. We — again, we mentioned how many stars — I think you said 10^{22} at least — are in the visible universe. We don't have to make much of a case. It's highly likely that we're not the only life in the universe do we?

Seth Shostak: Yeah, well it certainly seems reasonable because if you figure that's not true, if we are the only life or even the only intelligent life in the universe, that makes our situation miraculous, and anybody who's familiar with the story of Copernicus *[laughs]* and so forth and Charles Darwin and so forth, I mean they know that if you think you're really, really special, you might be wrong.

Dave Eicher: Yes. *[Laughs]*

Seth Shostak: Everybody likes to think they're special. That's a result of their parents. But, you know, the parents are — and maybe we're not all that special. So indeed, I mean it seems reasonable to assume the whole universe has the same physics, same chemistry, it's the same everywhere. That's the great triumph of astronomy. And, you know, to think that — but it only cooked up anything interesting here, you know, that sounds a little suspicious. So yes, they're probably out there. I think that that's fair to say.

Dave Eicher: Now how do you feel that we would recognize life, and I'm talking about everything from microbes on other planetary surfaces in our solar system or elsewhere or, of course, the detection of — how different might life be from what we know on Earth? It might be very different conceivably, right, might it not?

Seth Shostak: Well, you know, one should be careful of saying, you know, they are going to be like us indeed because they don't have to be like us. But on the other hand, you know, it's also the case we're carbon-based life-forms. I sound like Spock. But carbon-based life-forms — and that's not really just, you know, the throw of the dice. You know, it could have been molybdenum-based life-forms on Earth or anything like that or even the silicone-based life-forms.

We're carbon-based because carbon is, to begin with, abundant. It's cooked up in stars in great quantities, so there's a lot of carbon around. But carbon, you know, has these four covalent bonds if anybody remembers chemistry class, and that means it hooks up with other carbon atoms — and hydrogen, nitrogen, and so forth — to make complex molecules. And that's what life is. I mean it doesn't seem that way when you get out of bed in the morning —

Dave Eicher: *[Laughs]*

Seth Shostak: But you're just a bunch of complex *[laughs]* chemistry. And, you know, carbon is best for that. So, you know, you might say, well, maybe not all the aliens are carbon-based, but probably a lot of them are. So they're that. And as soon as you start going down that path you say, well, you know, you don't get a whole lot of chemistry if you just sit around on a dry planet, but if you throw some liquid on the planet, then suddenly things happen.

So there's probably going to be oceans of one sort or another. You know, in the end you come back to saying, well, the best I can guess it's going to be *something* like that we've got. Certainly the details will be different. It won't be DNA; it'll be some other NA, who knows what it'll be. But, you know, the sort of the fundamental biochemistry might not be completely alien, if you will.

Now that's life, that's life. And within 10 or 20 years we may know whether this little discourse is actually true or not because we may find some bacteria under the sands of Mars or under the ice of Europa or some other place in the solar system, and then we can look at it and say, well, is it the same biochemistry, or is it not?

So we might know that. But when you come to intelligence, the game changes a little bit. To begin with, you know, intelligence is a lot more complicated than building bacteria.

It took 4 billion years to build something intelligent on Earth, at least by out standards. And so, you know, there's the question of whether that happens a lot, and we don't know, but the other thing is that maybe most E.T.s are not, you know, biological at all. They've moved on to artificial intelligence, and that has big advantages. It can, you know, obviously improve itself very quickly. And that's hard for us to do, but it's not so hard for machines. So it may be that the majority of the aliens *[laughs]* are not little gray guys with big eyeballs and, you know, members of a species that has billions of inhabitants or anything like that, that they're just machines. That could be. That may complicate our efforts to try and find them because it's unclear what machines have an interest in doing.

Dave Eicher: And you're saying that it's conceivable that some alien life would not innately understand English as well. Is that — you're shattering my illusion there.

Seth Shostak: No, no, no. Don't worry, they'll all speak only American English, they always do.

[Laughter]

Dave Eicher: Well, you know, it's absolutely true. I mean there may be — you mentioned methane on Titan and there could be many other solvents. And of course temperatures and pressures and other conditions would be over a vast range on planets throughout our galaxy and other galaxies. But really, I mean we're looking at lots of combinations that are different, but when we look throughout the universe, of course, with spectroscopy, chemistry is fundamentally the same. So we understand how things combine. The combinations could be different, the local conditions could be different, but life is life throughout the universe at the most fundamental chemical level, is it not?

Seth Shostak: Yeah, well I think that that's a reasonable thing to say. I do. Now mind you, as noted, the details could very well be different. I mean life on Earth generally uses 20 amino acids, as they're called. This is a kind of molecule that's used to — for making proteins. And, you know, they're 20 — but there are a lot more amino acids.

There're, you know, twice as many amino acids as are actually used by life. So maybe if you went to another planet and it had life, it would use a different set of amino acids. I mean there're all these choices that are made by, if you will, the accident that led to life that sort of determined how it's done. I mean we have this, you know, double helix molecule, DNA, that kind of defines our inheritance and is the blueprint for life and all that.

Well, you know, you might say any life-form's going to need a blueprint. If it can't reproduce accurately, it doesn't have much of a chance. But it doesn't need to be a double helix. I mean it could be something else. I mean — so all these things are kind of, you know, up for grabs in a way. So I — you know, they're not going to be identical, but they're going to be some things that are probably similar, as to say carbon-based or that kind of thing, yeah.

Dave Eicher: And I mean it's worth noting that of the several hundred amino acids, glycine, the simplest of all the amino acids, exists in Comet Wild 2 from the Stardust mission. They're the only comet that we've sampled and returned a sample of to Earth. The simplest amino acid was contained in that matter. So that's pretty neat stuff as far as sort of an implication of the commonalty of life out there, perhaps.

Seth Shostak: Yeah, absolutely. No, that's one of the interesting results of the past 10 or 20 years that you find that, you know, some of these almost organic materials — you know, there's a whole question of what you mean when you say "organic" — but even at the local Whole Foods there's some —

Dave Eicher: *[Laughs]* Yeah, right.

Seth Shostak: You're going to —

Dave Eicher: Don't eat any food with these bad chemicals in the food, you know, for one thing, right? Yeah, yeah.

Seth Shostak: Yeah, it's just protons and neutrons; it won't hurt you.

Dave Eicher: *[Laughs]* Seth, you mentioned that Hollywood always presents not only aliens who are English speakers, but usually, they're more fun this way, they're hostile. But here's a question for you and I know I've heard you speak a little about this in the past. Are we actually in greater danger form ourselves on this planet, taking care of the planet, but also in terms of depleting the resources that we need for life on Earth?

Seth Shostak: Well, you know, there are many people who subscribe to this kind of apocalyptic view that we're, you know, on the verge of doing ourselves in. I'm personally kind of a little more optimistic than that. I think we'll find a way out of these problems. But there's no doubt that some of these threats, I mean to the environment, are just due to overpopulation or just running out of stuff; all these are threats — nuclear war if you're into that — I mean these are all things that, you know, could indeed threaten our *[laughs]* existence here. You might say, "Yeah, but are those any worse than, you know, some alien visitors coming down and incinerating Earth just because they don't want the competition in the used car market?" Or whatever.

Dave Eicher: *[Laughs]*

Seth Shostak: But, you know, the answer is, look, they don't know about us yet. That's my guess. Because we've only been broadcasting high-powered, high-frequency radio waves into space since the Second World War. So, you know, that means the most distant signals are only 70 light-years out, and the aliens that are more than 35 light-years out haven't had enough time to pick out those signals and then send their rockets back here and do damage. So I think that in the short term there's absolutely no danger *[laughs]* from aliens. They don't even know we're here or certainly they don't know we're here and have had time to get here, if that's on their minds. So I would say that in the short term we're much more of a danger to ourselves than the aliens are. Over the long term, you know, that could be the other way around.

Dave Eicher: Mm-hmm. And let's talk about UFOs. We — what is the Seth Shostak brief history from the post World War II era up to the present of the credibility of UFO sightings and your feelings about physical visitation of other species?

Seth Shostak: Yeah. Well I would certainly welcome that because I think it would be interesting and it might —

Dave Eicher: *[Laughs]*

Seth Shostak: — guarantee my employment. But I — you know, I hear from people every day about UFOs. People — mostly, they're people who call me up because they've seen something or they send me photographs. Today I got a fairly abusive email, a long one, that was sent to not only me but everybody who's on the payroll here *[laughs]* I think, everybody they could think of, saying that, you know, we're totally remiss to not investigating the UFO sightings of a guy by the name of Billy Meier who's, as I recall, in Switzerland. His UFOs look like little end plates held on a string, you know, above his backyard. Obviously, we don't *[laughs]* — but you don't dare say that.

Dave Eicher: *[Laughs]* Oh, no.

Seth Shostak: But, you know, look, these people who call me are not pulling hoaxes. They are — you know, they're all sincere, and so I — you know, I answer — try to answer them, try and help them, but honestly, my take is this: If there were good evidence of alien visitation, it wouldn't be confined mostly to witness testimony, which is very unreliable in science. It's, by the way, also unreliable in crime investigation, but that's something else. So, you know, the fact that some pilot says that they've — or an astronaut says that they've seen UFOs. That's not science, that's somebody telling you a story, and, you know, it's interesting but it doesn't prove anything.

If you had physical evidence, that might prove something, so the facts are, you know, UFO sightings in the modern year go back to just after the Second World War, so *[laughs]* again, even if there's been 70 years of that and we still don't, you know, have an exhibit in the Smithsonian with alien crafts stacked up or something, something. We don't have that. And to me, I think that that makes me very skeptical because if we were really being visited, I think in 70 years you would convince or you would get some evidence that was convincing. And many in the UFO crowd will say, look, you know, the government has convincing evidence, but they've kept it secret, and I don't buy that because that's an argument from ignorance. You know, there's good proof but I can't show it to you. I'm sorry, I can't believe that every government in the world is keeping this quiet. It just seems to me bizarre.

Dave Eicher: Too big a conspiracy, and you would think at least one of these UFOs would have landed in Central Park, collected us up and taken us off to dinner at Tavern on the Green by now.

Seth Shostak: Well, you know, as long as they pay, yes.

Dave Eicher: *[Laughs]*

Seth Shostak: I'm of — that's right. The idea that the — only the governments can get to the evidence is also strange.

Dave Eicher: Yes.

Seth Shostak: I mean that's — isn't true of any other physical phenomenon, but there you go.

Dave Eicher: Now let me ask you this question as well: How would see the potential detection of extraterrestrial intelligence, how would that change us as a species? Obviously, there would be profound psychological, moral, religious, philosophical, political — this would be on the great, great earthshaking moments in history, would it not?

Seth Shostak: Yeah, I think so. I did a poll many years ago. I just, I don't know, sent out letters to 20 or 30 science writers at newspapers, back when there were newspapers. And I asked them, you know, how would you rank the story of the detection of a signal coming from extraterrestrial intelligence as a news story? You know, big, small, what? And everybody wrote back the same.

They all wrote back this would be the biggest story every, although one guy said maybe the assassination of Kennedy was bigger. That was the only exception. All the rest said it was the biggest story ever. I think that's true. I think it would be a big story. I don't — you know, I don't think people would start rioting in the streets about it.

I mean they're not going to riot in the streets about it. They're just going to say, "Wow, that's interesting, let's hear more." Certainly, you know, the claimed detection of fossilized microbes from this martian meteorite in 1996 — it was a very, very big story, but people didn't quit their jobs and riot in the streets. So I think that that's what it would be. I think there would be a lot of interest. And of course, every telescope in the world *[laughs]* would be aimed in the direction from which this signal is coming in the hope of learning more. So you would immediately make this the most intensely studied part of the sky, which could only be a good thing.

Dave Eicher: Yes, absolutely. And perhaps it would be, if anything, an enormous dose of perspective, and God knows we need more perspective on this crummy little planet with some of the things that go on down here. But let's just — now we only have a couple of minutes, I'm afraid, left, Seth. This has been wonderful. But let's talk — can you talk a little bit — and clearly, the detection of extraterrestrial life would be a big one, but aside from that one, the obvious, where do you see the future of SETI over the next 5, 10, 15 years as a movement, as a project, as a part of science? Where is SETI headed?

Seth Shostak: Well that's really a good question, Dave. I — of course, my immediate concern is that there's enough money to keep doing it because, you know, SETI becomes very much less interesting if you're not actually doing any experiments than you — just obviously not.

Dave Eicher: *[Laughs]* It's much harder to get a result that way, yeah.

Seth Shostak: It is, it is. And you can say, well, serendipity. You know, maybe somebody else doing something else. That could happen, but you know, so that's my first concern. But given that you can find the money, if that turns out to be the case, then I would say the most important things that are going to happen in the short term are going to be increases in sensitivity and speed of the experiment.

This experiment isn't the same today as it was five years ago thanks to, mostly, computer technology. The speed of the experiment keeps going up. So that's good. You're looking for a needle in a haystack, and it's much nicer if you can go through the haystack with a shovel instead of a teaspoon, and that's kind of what's happening. So there's that.

But the other thing is we're also — you know, there're all sorts of experiments to find exoplanets, so we're learning more about what's out there in terms of planets that might be like the Earth. That's — that can only be a good thing. We're also developing more and more optical SETI experiments. There're new telescopes coming online that could help. The Square Kilometre Array being built in — mostly by the Europeans.

And that telescope, which will be I think in both South Africa and Australia, you know, that's a very big thing. And while it's going to be used for astronomy, you can simultaneously use it for SETI, at least for some SETI experiments. And it's — you know, it's a huge antenna, so, you know, that will play a role. So the development of new technologies, the speed-up of the search due to the improvement in computers, and the fact that astronomy keeps telling us — and it didn't have to do this, but it is telling us this — that the prospects for life seem to be getting brighter rather than dimmer.

Dave Eicher: Fantastic. Well what a great way to end. And I regret to have to say this, but we've run out of time. This has been a fabulous hour, and I thank you so much again, Seth, for joining me today.

Seth Shostak: My pleasure, Dave. Always good to speak with you.

Dave Eicher: Thank you and good luck with everything you're doing. We'll talk to you soon again.

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