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Speaker key:

SM: Sarah McConnell, producer and host

AS: Audio Sample

MW: Matt Wallin

BA: Bob Ash

MS: Michael Summers

DG: Denise Gillman

Transcript:

00:00:00

SM From Virginia Humanities, this is With Good Reason. In the Blockbuster movie, The Margin, Mark Watney, played by Matt Damon, travels with a team of astronauts on a mission to Mars. But when they arrive, things go horribly wrong and Mark gets left by the crew. After over a year stranded on Mars, Mark escapes by using something called a Mars ascent vehicle. It's based on real life technology that converts Mars atmosphere into oxygen for fuel.

AS Watney, how you doing down there?

Not good. I'm anxious to get up to you. Thanks for coming back for me.

Well, we're on it. You've been pulling some serious G's so it's okay to pass out. Remote command.

Go.

Recovery.

Go.

Secondary recovery.

Go.

Pilot.

Go.

Pilot.

Go.

Captain, we're go.

[inaudible], we're go for launch.

T minus 10, 9, 8, 7, [inaudible] release. About 5 seconds Watney, hang on.

See you in a few, commander.

4, 3, 2, 1.

SM I'm Sarah McConnell, and today on With Good Reason, we talk with the person who helped develop the technology that might allow sustained flight in Mars atmosphere. And later, a former Hollywood visual effects artist shares his experience at Mars. The Mars conference, that is. But first, that Mars ascent vehicle from the movie, The Margin, converts Mars atmosphere into oxygen for fuel. Essential if humans are ever to visit the red planet. And soon, the real life version of that design is scheduled to go to Mars. Bob Ash created the prototype for the design decades ago. He now has second thoughts about manned missions to Mars. Bob Ash is a mechanical and aerospace engineering professor at Old Dominion University. Bob, another Mars rover will be launched from Cape Canaveral, Florida in July. There's apparently a very narrow window for when these launches can happen. Why is that?

BA Well, in order to get to Mars, unlike the moon, you have to take advantage of the sun's gravity, and so you wind up moving from an Earth-bound orbit into a solar-bound orbit, and then you have to get to Mars. It turns out it's about 27 months between successive opportunities to take advantage of the sun's gravity and get to Mars' orbit when Mars actually is nearby.

SM	Does the same thing happen on the return trip?

BA	It does, but it's a little more often primarily because you're traveling toward the sun rather than away from the sun, so that happens about every 100 to 150 days.

SM	You're going to be watching this particular launch with even more excitement than you might have observed past launches. That's because it's carrying a prototype of something you invented years ago.

BA	That's correct. It's called Moxy and it's a Mars oxygen generator experiment that will be converting Mars atmosphere, which is 95% carbon dioxide into carbon monoxide and oxygen and oxygen will be separated so that it can be used someday for life support and rocket fuel.

SM	Was this basically what we saw in the movie called The Margin?

BA	Yes, it was. Matt Damon, who played the astronaut who was stranded on Mars and, in order to leave Mars, he had to get to the Mars ascent vehicle which was using oxygen as part of its propellant manufactured using this technology.

SM	Why can't we just bring the oxygen with us?

BA	We can. The problem is, when you want to bring a sample back or, better yet, you'd like to someday bring humans back, the rocket propellant that you need for those kind of missions, represents roughly 80 percent of the total mass of the return vehicle. The oxygen is the heaviest part of the rocket propellant, so a human mission to Mars wouldn't really be practical if you had to carry that much fuel from Earth, and you'd be better off making it at Mars.

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SM	Is the oxygen we're looking for on Mars for the fuel or for people to breathe?

BA	Well, the first use of this oxygen will be for bringing a sample back from Mars, which we've been trying to do for more than 50 years.

SM	Bringing a sample of what?

BA	A sample of probably Mars dirt which we call regolith, or better yet, signs that there used to be biologic activity on Mars. Those are all very interesting questions which we can only answer in a laboratory on Earth.

SM We haven't brought dirt or rocks back from Mars?

BA Nope, because their return vehicle is part of the payload and it's too heavy. I got started on that problem in 1978.

SM That is actually weirdly what led to you coming up with the invention to create oxygen on Mars.

BA That's correct. In 1976, NASA had become the first space agency to successfully land a lander basically on another planet. THey landed 2 on the surface of Mars. That data was so incredibly exciting that NASA was asked, "So what are you going to do next?" And they weren't really sure, but they finally decided, what we really needed to do was come up with a system that we could bring rocks and other samples from the surface of Mars back to Earth. It became painfully obvious that the return rocket, which had to be part of the payload that was launched from Earth, was so heavy that we didn't have any rockets that were large enough to go to Mars, land the return vehicle as part of the payload, and come back. So, this engineer at a jet propulsion lab named Warren Daller and I were asked to look into the feasibility of making rocket fuel at Mars. Now this was 1977. And I don't know about you, but if you were alive then, most of your audience probably wasn't, your reaction was, "are you crazy? What are they thinking that they can do?"

SM Make fuel on Mars, right?

BA Yeah, using Mars resources, so you weren't–you didn't have some kind of magic chemistry. You had to figure out what kind of things you could use at Mars that would make rocket fuel.

SM What did you all think about?

BA Well, we thought about some really crazy stuff. We were talking about drilling a home in the surface of Mars that was deep enough so you could use it like a cannon. It was all kinds of weird stuff. But we only did that for 1 day. And we told the people at jet propulsion lab that we were doing all the planning, we've looked at it and we don't see any obvious way to do that. But here at Old Dominion University, I teach thermodynamics and heat transfer and subjects like that, and thermodynamics is where we learn how to burn gasoline and make vehicles run. And it turns out, if you probably have looked into this at all, that the 2 products that are produced by these combustion reactions are carbon dioxide and water. Well, Mars atmosphere is 95% carbon dioxide and, at that time, we knew there was water ice on the polar regions of Mars but we didn't know whether there was ice or water anywhere else. So it was perfectly logical to suggest that maybe you could come up with a way of capturing water, and there's a process in chemistry called the sembodiet process, and you could use that and make methane and oxygen out of water, ice, if you could get a hold of it. And Mars atmosphere. But, because of the unknown availability of water, other than in the polar region, which would have been very difficult to land, there had to be a better way. And that's when I realized that, well, if the rocket propellant is 80% oxygen and 20% methane or whatever other chemical you want to combust, you could save enough mass that you could actually make it work with current launch vehicle capabilities. The challenge at that point was to convince NASA that this was a good idea.

SM Did you find somebody at NASA who was interested?

BA Well, Warren Daller was, my partner. NASA headquarters would look at what we were talking about and tell us, "well, we know how to do that already. What do you want us to fund?" And they just didn't generate any real interest. We wanted them to fund the research that would enable NASA to make a machine that would extract oxygen from Mars atmosphere.

SM So when did you get money to keep working on this device?

BA Well, as luck would have it, the Planetary Society had just become a rather significant, I guess it's an international organization. And they were quite interested in both human missions to Mars and also collecting a sample from Mars. So we were successful at Old Dominion University in earning a grant from the planetary society and, at the same time, the NASA headquarters had started this program called an undergraduate space design program and we got funding from there. So, over a period of about 4–between 4 and 5 years, we actually build a Mars oxygen separator demonstrator.

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SM Did your contraption work way back then on the 1st try?

BA Our contraction worked for about 1 second.

SM [laughs]. But it did work for 1 second!

BA It did work for 1 second. And we used a very good approximation of Mars atmosphere, but the problem that a bunch of mechanical engineers have when they don't know enough about batteries and the like was that if you apply too big of a voltage across your backward battery, you would burn it out. And we applied too large a voltage and we burned it out. And that cell costs $10,000 which was a lot of money for a university. And we couldn't replace the cell.

SM So you didn't get to do a million more tries after that?

BA [laughs]. We didn't get to do but 1 try. We demonstrated that it was feasible. If we were mathematicians, we would say the solution is obvious. But as an engineer, you've gotta make it run for more than 1 second.

SM And the solution basically was less power, right?

BA The solution is apply a lower voltage which is less power.

SM Isn't that fascinating that it was that simple in some respects?

BA The amazing thing about the discipline of engineering is almost everything we do, if you can break it down to a simple enough problem, it's usually things that–like you just said–are, "well why didn't you know that?" Well, we didn't know it until we tested it. That's why we build things and test them.

SM It's so interesting. You used to say that you would welcome a call to travel to Mars someday, and wanted to see manned missions to Mars. But now you have reservations about that. What's changed for you?

BA At the time, we were building our conceptual models for how we could both bring samples back and humans back. We didn't know a whole lot about the environment in which these folks were going to have to survive. That was the first thing. And the second thing, in 1977, 1978, there was no Apple computer. There was something called a commodore computer which probably, your refrigerator, if it's digitally controlled, has more electronics than that computer. So, if you try to do non-human explorations of Mars, it just didn't make a lot of sense. Now, because of all of the things we're doing with robotics–the drones, and things that we're using in military applications...we have drones that are doing extremely dangerous operations in nuclear reactors and things like that. We now have robotic capability that can do virtually all of the things that humans do. Not nearly as rapidly and they certainly don't think like humans but the problem that they solve is, if they get radiated at Mars, we'll have a sad day because they robot stopped running, but we aren't going to have any fatalities. The radiation exposure that humans will be subjected to if they continue to try to get to Mars using chemical propellant technology is such a risk that it's very hard for me to believe that all of our astronauts will survive from the point of leaving Earth until they return to Earth.

SM Where does that radiation hazard come from?

BA Well, the problem is, it doesn't just come from the sun. If it did, we would be open because we can orient the spacecraft in such a way that it's always pointing a shield toward the sun. But the really severe radiation is called HZT, but the quick word is it's a heavy molecule traveling at near the speed of light and they can come from any direction. And if you're in space for 100 days, the probability of such an event is high enough that I think it's not a good idea for humans to go unless we have a much stronger case after our robots have done all the work.

SM What has been exciting you recently as you've seen new developments regarding space?

BA My students are giving me a really hard time because I told them that I was not sure that the black holes that have been postulated are really there. And if you have followed that current reporting, it looks now that a black hole has been observed telescopically which, for me, is quite fascinating. And hopefully we'll begin to understand how we can go about proving it's actually an effect. You know, if we ever want to travel back in time, that might be the way to do it.

SM That's interesting. So you were something of a skeptic on black holes before?

BA Yes.

SM And not at all now, right?

BA Well, I'm still, I'm saying I've gone from believing that there was a 90% probability that the mathematics were actually describing the physical effect. Now I'm believing that it's probably 98 or 99% probability.

SM [laughs].

BA The excitement in science, and that's what makes it so hard for the average person to understand is, the scientific world is not blcka nd white. There are black and white areas, but most of what we do in science and engineering is gray. We're trying to push the gray and the white boundary where, if white is fully understood, we want to gain more knowledge. And that's why this is always going to be fun.

00:15:33

SM [music] Bob Ash is a mechanical and aerospace engineering professor at Old Dominion University. Coming up next, we talk with someone who actually went to Mars–well, sort of. Matt Wallin spent many years in Hollywood working as a visual effects artist on movies such as Star Wars, Watchmen, and Jurassic Park. He's now a communication arts professor at Virginia Commonwealth University. He recently got the chance to attend the prestigious Mars conference hosted by Jeff Bezos. He shares his experience at the Mars conference and walks us through one of his favorite movie scenes that he worked on during his career. Matt, you gave a talk at the Mars conference last year, but this year I understand it was cancelled.

MW Yeah, it was cancelled this year as a result of the ongoing coronavirus. That conference was actually going to take place in March this year out in Ojai, California. And that event was cancelled this year.

SM How about you? How are you and your family doing so far?

MW We're fine, I don't know anybody personally at this moment who's had the virus, but we're just sorta holed up in our house here. My 16 year old son I think is probably the whole who's going the most stir-crazy.

SM Right. Tell me about the Mars conference. It's hosted by Jeff Bezos I understand. What's the focus of it?

MW Yeah, Jeff Bezos had this idea of creating a conference where he would bring together people from various disciplines. And Mars is an acronym which stands for machine learning, automation, robotics, and space. And so the conference brings together people from all manors of disciplines from the sciences, from space exploration, from machine learning, computer science, robotics, and you wind up with a host of different kinds of personalities engaged in all different kinds of research. And then there are also some artists and creators who are invited–people who maybe inspire some of the pursuits.

SM And why Bezos? Is he particularly interested in space?

MW Yeah, I mean Jeff Bezos has his own space program, the blue origin program. It's similar to the SpaceX program. I guess they're kind of competitors, you might say, in some of the privatization and commercialization of space. But I think, also, Bezos is a guy who, aside from his obvious business dominance and success in his area with Amazon, he's always been someone who's really passionate about and very interested in space exploration and science in general. And I think this conference, I think, for him, is really an extension of those interests and a genuine altruistic and optimistic desire to create a collection, a gathering of people who can exchange ideas and information for the betterment of, you know, the human future, you know? I think it's a very optimistic conference.

SM You were on stage with Mark Hamill who played Luke Skywalker in Star Wars?

MW That's correct. Yeah, I was asked to come and be a moderator for one of the evening talks that takes place at the conference. And I spoke with Dennis Murin and John Knoll. Dennis Murin is one of the top Academy Award winners in the world of visual effects. He did all the visual effects supervision for Star Wars, ET, Jurassic Park, Terminator 2, and then John Knoll, he and his brother, Thomas Knoll, are the co-creators of Photoshop, a little software tool that you may have heard of. And I got to interview them and moderate a conversation about visual effects and visual effects techniques and sort of the convergence of science and problem-solving. And then I spoke with Mark Hamill as sort of a surprise guest afterwards and, in speaking with Mark Hamill, we talked a lot about his career but also about how it's really the artists who inspire the scientists to pursue a lot of their trajectories and career paths. In Star Wars, Luke Skywalker loses his hand. And he receives a robotic hand at the end of The Empire Strikes Back. And the DARPA projects built what they called a Luke hand which is a robotic hand that can be hooked up to somebody who's lost their hand or their arm, and opposable thumb and fingers that can allow them to grip and hold things. And so we talked about that some and how it's really artists who inspire science and sort of science fiction as a way to kind of envision a potential future.

SM Tell me about your own talk there. It was about the arts and science in technology. What did you want people to understand about the creative enterprise?

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MW It was initially sort of about visual effects. You know, in visual effects, for motion pictures and television, what we're really dealing with on a almost daily basis is problem solving, and it's often complex problem solving to achieve a particular creative goal. And it can range from the dinosaurs in Jurassic Park to spaceships, dog fighting in outer space, to a photorealistic monster from outer space. And I think when we were talking at the Mars conference, it was about trying to reconnect back that creative process with problem solving and how that creative problem solving is really no different than the science based problem solving. For example, there was a movie I worked on called the Watchman, and not the TV show The Watchman, that was just on HBO, but the Zac Snyder movie. And there's a shot in that where there's a ship, the owl ship, and it emerges from underneath the water on the East River, and as it goes up into the air, the speed changes and it flies off towards the moon. And one of the things in that shot that was so complicated was creating the refraction of the light of the ship as it was nearing the surface of the water. And then as it penetrated the surface of the water in the East River, we had to create the wave and the splash and then the splash of the splash as well as the engines that are sort of making the ship go up into the air. The engines were backlighting the water, and they're aerating the water, so creating a bunch of different bubbles and interaction. And so to create all of that, we had to do research into areas of fluid and thermal dynamics, and how does water behave. And to really study, well what happens if something that's emitting a lot of thrust vectoring and what not and is illuminated...what does it look like? I think the most exciting thing about visual effects is that everyday it's a new challenge. And the challenges that you confront lead you into areas of study that maybe you wouldn't have engaged in otherwise like, I worked at Sony Imageworks one year one I Am Legend and we created these hemocyte characters. And one of the most exciting things about that was the idea of subsurface scattering of light. And now it's fairly commonplace in computer graphics but, for a long time, it took a while to sort of understand and find and develop that sort of technique to create that look if you were to hold a flashlight behind your fingers, sometimes I remember doing this as a kind, like oh look it's like an x-ray. But what you see is you see that kind of glow of the skin illuminated. And the light permeates a sub-surface kind of fluid body of the skin. And it goes only so far through. And you can see that a lot if you see someone backlit in the sunlight, and you look at their ears, the cartilage in their ears, you can kind of see that effect. And to recreate that in computer graphics was a difficult problem to solve but now it's one that is fairly commonplace.

SM I think we take for granted how often artists inspire science and scientists. Give me some examples that you have thought about that are so clear.

MW I think the ones that always come to mind for me are things that come from movies, and science fiction too if you look back at HG Wells' The War of the Worlds and the way in which the aliens are eventually defeated is because of their microbiology. Like there's a virus that eventually takes out all of the aliens, right, they're unable to survive on Earth because they haven't had the years of immunity built up. And I think that's a really interesting thing that could inspire, certainly, people into engaging in virology or microbiology as a research field.

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Um, similarly, I do think Gene Rodenberry in the 60s with Star Trek really created something, a vision of the future, of a united humanity as well as sort of other worlds and other alien races nad technologies like the communicator, the replicator, warp speed, and things like that, I think were so inspiring to people who then pursue careers in 3D printing, telecommunications, computer science, and space exploration.

SM You and others were electrified by Star Wars and Star Trek. What do you think is capturing the excitement and imagination of the new generation?

MW [laughs]. I mean, it's a great question. I feel like what's so interesting about that is that we now live in a totally different landscape of media. Media today is so much more porous. There are so many ways in for the individual. And there are so many niche areas too. When I was a kid in the 70s, Star Wars was the motion picture event, you know, that changed the nature of movies. Yeah, I don't know that there are things that are that way anymore. That is the singular event. Because there is so much more content being generated. And for my students, it's everything from stuff they're watching online, series they're into online, to, you know, manga comics from Japan to students who are inspired by watching SpaceX booster rockets landing autonomously on platforms at sea, and, I mean it could be so many things, real world and fantasy.

SM What do you think we lose as a society if we prioritize science over the arts or leave the arts out of the equation?

MW I think we would lose some of our humanity I guess in a lot of ways. Like what is science? What is science for? What is the pursuit of knowledge about? Like, why do we do those things? You can't separate the arts and the humanities from the sciences in that we're so broad in our engagement and experiences as people that it's almost like saying, if you were to separate, then what do we lose? Well, then we'd all be robots in a way. Like, I think the arts really are a key and critical piece of everything that we do.

SM Well, Matt Wallin, thank you for sharing your insights on With Good Reason.

MW Oh, my pleasure. Thanks so much for having me. [music].

SM Matt Wallin is a communication arts professor at Virginia Commonwealth University. Welcome back. This is With Good Reason. Since its debut in 1966, the science fiction series, Star Trek, has introduced fans to hundreds of imagined worlds, each with different compositions and life forms. We haven't yet found planets that look like our own, but scientists are identifying thousands of new planets, including 1 that spews diamonds the size of your fist. And another one where it snows crystal and rock. According to NASA, there are 4,144 confirmed exoplanets. These are planets beyond our solar system. Michael Summers is the co-author of Exoplanets: Diamond Worlds, Super Earths, Pulsar Planets, and the New Search for Life Beyond Our Solar System. He's a professor of physics and astronomy at George Mason University and has served on the mission teams of several NASA space probes. He's continually surprised by the discoveries we're making. Mike, you and I were taught that there are 9 planets period. And yet, in your long career, and especially recently, you're finding planets around every corner.

MW Well it's almost entirely recently. We discovered the first planet beyond our solar system in 1991. And then we found a couple more in 1994 and 1995. And then I think it was really 2007 wherein the field of exoplanet science really kicked in. The kepler space telescope has been very successful at finding planets around other stars. And now we are discovering new planets at the rate of about 2 or 3 per day. And that rate is increasing, so just think about that. Everyday, I have to look at the exoplanet encyclopedia when I go into work to see, what planets do we know about today? And it's not just the numbers of the planets. It's a whole new category.

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I grew up that there were 9 planets. And then we categorized those into 2 types–rocky planets like the Earth, Mercury, Venus, and Mars, and then the giant planets, Jupiter, Saturn, Uranus, and Neptune. Well that really wasn't representative of what we're finding.

SM You have one in your new book you call diamond planets. What's that?

MW Diamond planet, yeah! Well, we're finding that planets come in very bazaar compositions. Things that we didn't expect. And there are a couple planets that appear to be made out of, if not pure, almost pure carbon. And so a planet, you know, is going to be a lot of mass under a lot of pressure, and so under high pressure, we know what elemental carbon is. And that's crystal and diamond. But this is one of the most bazaar planets you could imagine. Not only is it made out of diamond, where you have a mantle maybe 10,000 kilometers thick of crystal and diamond, the core of it is under such high pressure, 100 million times the surface pressure on the Earth, that the diamond flows as a liquid.

SM Huh.

MW At that kind of pressure, liquid diamond would force itself up through fissures and cracks in the crust, and explode out on the surface a lot like magma does on the Earth. And, you know, we get volcanoes that way. Well, in 55 Cancri e, we would get volcanoes, but it would be liquid diamond spurting out into the sky, crystallizing as it cools, falling back onto very black velvety surface, and the diamonds would probably be about the size of your fist as they crystallize and cool. So it's a very crazy place.

SM What is the name of it again?

MW 55 Cancri e.

SM Does it sound like a Beatles song? Couldn't you just see this?

MW [laughs]. I wish somebody would make a song for this planet. It deserves it.

SM Then you have described planets that are all water.

MW Yeah and I'm not talking about covered with water. I'm talking about water through and through from the surface all the way in, maybe 80 or 90% to the core. The core's probably made out of nickel and iron and rocks and stuff. But you're talking about a water ocean. Maybe 10 to 15 thousand kilometers thick.

SM There's also a category that you're finding that you've dubbed rogue planets. What are those?

MW Right. Rogue planets. Me, I find these the most intriguing of all. For one reason, there may be more of these than any other kind of planet that's out there. And they're probably more bazaar, more different than anything in our solar system than we can imagine. And so, these are planets that don't orbit stars. They have been ejected into the intersolar medium and wander out between the stars. We haven't found very many of these. Just a handful of them. But they're hard to detect. The fact that we've found any of them means that there're probably lots of them out there. In fact, there could be thousands of times more of these than those bound to stars. Many of us scientists grew up with science fiction, but none of them really matched the bazaar-ness of reality. We found planets that orbit 2 stars, we found planets that orbit 3 stars, we found planets that orbit 4 stars, and we don't even know how you'd dynamically do that. How can that be stable for long periods of time? Yet there it is. I mean, we find planets that are so close to the central star–the side that's facing the star is a magma ocean. The magma evaporates into the area above the planet and forms an atmosphere of vaporized rock. It flows around to the night side supersonically and it cools rapidly down to temperatures below the freezing point of water. As it does so, it freezes out in the atmosphere as rock snowflakes that fall onto the surface of the planet.

SM [laughs] You're making this up.

MW No I'm not making it up! They will be crystalline rocks. Tiny little crystalline rocks that fall out of the atmosphere onto the surface. That's the kind of thing that we're finding.

SM So what is our field of exploration? We're just looking within our own galaxy.

MW But our galaxy is pretty big. There are about 400 billion stars in our galaxy. That's about 10 times the number of people that have lived on Earth in Earth's history. For each of those stars, there are probably 10 planets. So you go outside at night, you look in the sky, and just think about that. When you look in the sky and see a star, on average, there are about 10 planets around it, probably 2 or 3 are Earth-like, and there are probably 1 or 2 that would even be habitable for simple life. So, that means that there are 10 times 400 billion planets in our galaxy.

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More habitable planets than the number of people that have ever lived on Earth. And then if you extrapolate that to all of the galaxies in the visible universe, that means that there are more habitable planets–not planets but habitable planets–than the combined number of heartbeats of all the people that have ever lived on Earth.

SM So, of course everybody asks you, "what do you think is the possibility of A) life, and B) intelligent life, life equal or surpassing ours?"

MW Well, we're finding that life on Earth is incredibly hardy. We find life deep underground, we find life at the base of glaciers, we find life that lives at the base of volcanic pools around volcanic vents. We find life at the top of the tallest mountain, life that can live in the coolants around nuclear reactors. So life is incredibly hardy. We call this type of life extremophiles. This type of life could live in the clouds of Venus, underground on Mars, inside 3 of the moons of Jupiter, inside 3 of the moons in Saturn, probably inside one of the moons in Neptune and inside of Pluto. So simple life can live in many many places. There are habitable planets for simple life all over the place. So, if the process that led to life originating on the Earth is in any way common to planetary systems, there should be simple life all over the place. Now, to go from simple life to complex life, a lot happened. In Earth history, we had simple life present about 3 and a half billion years ago. But it was only half a billion years ago that we got complex life forms and the body plans that we're familiar with today. And then it's only in the past, you know, few million years that we've had hominids, you know, humans, and then more recently, homosapiens. That path is uncertain because we've only got information on 1 way to get from simple life to complex intelligent life. Are there other ways? I would guess almost certainly given the complexity of the universe around us. Are there ways of getting intelligent life that's different than ours? Almost certainly. I think once you get any kind of life on a planet, evolution is going to drive that to more complex to more hardy, more adaptable organisms. I mean, they couldn't survive otherwise. And intelligence has survival virtue. So eventually you'll get intelligent life if you get simple life. Now I'm oversimplifying and there are many unknowns and the truth is we've not discovered it yet. So it could very well be true that we are the only living thing in the universe. I would find that more astonishing than a universe that's filled with intelligent life.

SM You're not just speculating. You are actually systematically looking for this and studying it.

MW Right. And we will be looking for signatures of life on planets around other stars. And that's not easy to do. We have to be quite honest. We're looking for signatures of life on a planet light years away is just plain difficult. Life could be much more common in these ocean worlds and on the surfaces on planets. Maybe life rarely evolves on the surface of a planet because that's too hostile. You know, it's exposed to ultraviolet radiation from a star, asteroid impacts, maybe subsurface oceans are really where intelligent life develops and evolves. How would you detect intelligent life inside of an ocean world around a distant star? We don't know. Now if they're intelligent enough to send signals out into space or to send signals between themselves and we detect some of the leakage of that, that would be a different thing. That would be intelligent signatures. But looking at just the residues or the byproducts of life, of organic life, may just be one of the ways of doing it, and there may be more ways of doing it. We just haven't discovered them yet.

SM If we can't see these planets, we're not seeing them with our telescopes, we're inferring them. Right?

MW Well, most of them, yes. Okay, we–

SM So, so, the diamond, the liquid diamond and the rogue planets and the all water planets, and the giant oceans thousands of kilometers deep. How do we know?

MW Well, uh, we know because of the laws of physics. And we know gravity pretty well. ANd so when a planet moves around a star, it tugs at the star. And so when we see tugs like that around distant stars, you could infer things about the planet, so we have subplanets that are incredibly that are gonna be metal. And some planets that are low-density that could be hydrogen, a gas. And in intermediate are planets like the water planets and the diamond planets, but they measure the density, that gives us a good handle on the internal composition.

SM What do you want to see happen now?

00:40:18

You want to see space travel improved, or do you just want farther and farther probes?

MW Humanity is going to go into space, okay? That's the future home of humanity, at least if we're going to survive for any long periods of time. And part of the reason is that the Earth is just too exposed. It's a dangerous place to be for thousands and thousands of years. You know, asteroids, impacts, huge volcanic eruptions, plagues, could easily wipe out civilization if we have all of our sort of eggs in one basket as they say. And so spreading humanity out among different planets would make humanity more survivable in the long term. And I think for commercial reasons, we're going to go into space. The resources on the moon and the asteroid belt, just dwarf the kind of resources that have been mined in the crust of the Earth in human history. I suspect that the 1st trillionaires are going to be the people that learn how to mine and transport in cells some of the raw materials that we find in the asteroid belts. Like, water, and carbon, raw materials that you can use to make propellants for rockets, and food for humans. And things like gold and platinum and Earth elements that we use to make computers. All that stuff is there and easy to obtain. When the Earth formed, most of that stuff condensed into the center of the Earth. But out there in the asteroid belt, they're just mixed with all the other rocks, and you go land on an asteroid that's the size of this building, so a few hundred meters across, and you just start mining.

SM The last time I paid close attention, it seemed like we'd come to the end of great NASA space exploration and we were all wringing our hands over what the next great project would be. But you sound as though we are thriving.

MW We're on the verge of having a major human presence in exploration again. It depends a large part on robotics and artificial intelligence. If we're able to build AI systems that can be simple, that we can launch say to an asteroid but yet complex enough that they can mine the asteroid for us, set it up so that when humans arrive, it's a turnkey operation.

You just open the door and walk in. Now, that's–it sounds like science fiction. But I think that that will probably be the next level of a serious advancement of human presence in space where artificial intelligence, where robots build the settlements before we get there, or at least pieces of them, so that by the time we get there, we don't have to worry about that aspect of it. We can go ahead and start exploring, or doing the next stage of exploration.

SM Well, Mike Summers, this is fascinating. Thank you for talking with me on With Good Reason.

MW My pleasure. Thank you.

SM Michael Summers is a planetary scientist and professor of physics and astronomy at George Mason University. He's the co-author of Exoplanets: Diamond Worlds, Super Earths, Pulsar Planets, and the New Search for Life Beyond Our Solar System. Coming up next, when the worlds of science and theater collide. Chaos theory is a branch of mathematics that has applications in disciplines like meteorology, physics, and engineering. But what about when chaos theory is brought to the stage? Denise Gillman is an associate professor of directing and dramatic literature at Christopher Newport University. She says a play about chaos theory introduced her to the world of science plays.

DG Yeah. The play that began this whole journey for me is a play called Arcadia by Tom Stoppart. As a young person, I really struggled with science and mathematics. But when I read this play when I was a graduate student, somehow though Tom Stoppart's goal to illuminate the ideas of chaos theory, I was able to understand it. It happens in 2 different time periods around 1812 in England and then the mid-90s. Tom Stoppart actually based the character Tom Acena on Ada Lovelace who was a brilliant mathematician. And she also is considered the first programmer. She's 13 years old and she's absolutely brilliant. And she actually discovers that this famous equation cannot be solved.

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SM Why did it speak to you, because you recalled your own struggles with math and science?

DG Well just, for me, when I read the play and I began to visualize this idea that there are forces that are above and beyond our everyday understanding of our existence, it elevated my thinking and I could visualize it because I could see the characters from the earlier time period and the latter time period. Their actions were beginning to intermingle, even though they were centuries apart. And it helped me to understand that an action that takes place centuries before can have an impact, a great impact, on a future time period.

SM I had never thought about there being so-called science plays. Can you tell me some of the plays you found?

DG Yeah, there are some classical science plays like Doctor Faust, and then there's also Galileo by Berchdel Brecht. Also, Inherit the Wind is considered a science play. But it's really only been in the past 30 years that playwrights are really turning to the stories that science has to tell. So we have playwrights like Tom Stoppart, we have playwrights like Michael Freyan with Copenhagen, a play that I'm working on right now is Photograph 51 by Anna Zieckler. It's a play that explores the race to discover the structure of DNA in the early 1950s. The 2 teams that were trying to uncover the secret of life. There was one team at Kings COllege in London, headed up by Morris Wilkins and Roslin Franklin, and the other team was at Cambridge, which was Francis Crick and James Watson. And in the early 50s, they were all racing to discover the DNA structure. And Roslin Franklin took a famous photograph called Photo 51, and this photograph revealed that DNA was a double helix structure. And her colleague Morris Wilkins shared this photograph with James Watson and Francis Crick and they took the information along with some other reports and they basically created the famous model that basically proclaimed to the world that they had discovered the double helix structure of DNA. And basically went on to win the Nobel Prize in 1962.

SM And that's the story most of us know. Not the behind the scenes story.

DG Absolutely. And once again, we're really beginning to uncover women's contributions to science, whether that's women like Roslin Franklin or Catherine Johnson from Hidden Figures or Ada Lovelace in a new place that's coming out by Lauren Gunderson called Ada and the Machine, where we learn about Ada Lovelace and her work with Charles Babbage. And the beginnings of a mechanical machine that would eventually become the computer. There are several plays written by a woman named Émilie du Châtelet. She was a mathematician, a philosopher, and physicist. And she was also the long-term lover of Voltaire. And she and Voltaire engaged in work to try to, in many respects, illuminate the ideas of Sir Isaac Newton. But in her work, she also began to champion the ideas of Godfried Litenits who was a German mathematician and scientist. And several plays had been written about her–one called Émilie Le Marquise du Châtelet Defends Her Life Tonight by Lauren Gunderson. Also another play called Legacy of Light, which also explores her life, primarily in the last 9 months that she was alive.

SM Tell me about the play you directed a while back called Constellations.

DG Ah, yes, beautiful play about love, the multiverse, and string theory, where we watch over the course of time, these two characters. They meet, have a first date, they fall in love, get married, there is a betrayal, and then eventually, as we move toward the end of their story, we learn that MaryAnn, the female character, has got cancer. And so we watch them struggle through her cancer and her demise. All of these milestones are told in 6 different variations. So we watch 6 different possibilities of how they met. So in 1 of those possibilities, she meets him and he is there with his wife. In another possibility, she meets him, and she's there with her boyfriend, once again trying to illuminate the idea of the multiverse, that there are multiple ways or multiple realities within our life. And any turn of a phrase, a funny look, or small adjustment, could absolutely change the course of our lives. And the way we go.

00:50:24

SM Well, Denise, thank you for sharing your insights with me on With Good Reason.

DG Thank you so much. It was great to be here. Thank you so much for the work you do. [music].

SM Denise Gillman is an associate professor of directing and dramatic literature at Christopher Newport University. She's also the creator of a new online catalogue of science plays. You can find the link to her catalogue on our website. With Good Reason listeners, we want to hear from you. What are you doing to cope with the COVID-19 changes? What's helping you? Give us a call at 434-253-0396, and that number is on our website. Major support for With Good Reason is provided by the law firm of McGuireWoods and by the University of Virginia Health System, using advanced cardiac imaging to better diagnose conditions before they become serious health issues, UVAhealth.com. With Good Reason is produced in Charlottesville by Virginia Humanities. Our production team is Allison Quantz, Matt Darroch, Allison Byrne, Lauren Francis, and Jamal Millner. For the podcast, go to withgoodreasonradio.org. I'm Sarah McConnell. Thanks for listening and I hope you and your loved ones stay safe. [music]