Blueshift - October 2015

Spontaneous Complexity

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Maggie: Welcome to Blueshift, brought to you from NASA's Goddard Space Flight Center. I'm Maggie Masetti. We're taking a break from our podcast hiatus to bring you a very special episode. We had an astronomy and physics undergrad, Jasmin Evans, visit us from the UK to learn more about what we do here at NASA Goddard. We had a cupcake birthday party for Nobel Laureate (and James Webb Space Telescope senior project scientist) John Mather and while we chatted and tried not to get chocolate all over our faces, he answered some questions for Jasmin. About why this is such an exciting time for STEM (science, technology, engineering, and mathematics), and the best way to encourage students to pursue it. The thing he said that resonated with me the most was this, that a lot of people imagine others are more talented than them, so then what's the point – but that his view is the opposite, if you're interested in something, why **not** try to go further than you are? On that note, I'm going to let Jasmin take it away.

Jasmin: During my week at Goddard I was lucky enough to meet John Mather, senior project scientist for James Webb Space Telescope and Nobel Laureate. I asked him about his own background in science, his advice to young people and his hopes for the JWST project. Everyone has a 'science story' of how they came to be interested in the subject, for me it was a physics teacher who made the universe seem like a playground of unanswered questions. I asked John what it was it that really made him sure science was for him. (one take, 14.20)

John: I think I was in the third or fourth grade and my parents had taken me down to the big museum in New York City where the planetarium show is and the bones are displayed so you can see evolution displayed right in front of your eyes, and the dinosaurs are enormous it's exciting for a kid and stories about volcanoes. I read about a volcano that just came out of a cornfield in Mexico in 1940 or something like that, and so I thought "Wow, this Earth science, this is all fascinating stuff". My parents actually read out loud from the biographies of Darwin and Galileo to me and my little sister, when I was about 8 or 9, so this is pretty amazing, a person could actually work on this.

My Dad was a scientist but he was studying dairy cows, and I thought I'm not very interested in these big old cows but somehow I got in to reading every book about science that there was to read in my public library. My public library came around to the farm every couple of weeks in a truck, so I'd go down every couple of weeks and see what books do they have about science? And I just read what they had. So that was how I spent my grade school, was reading books, and messing around in the basement with hammers and nails and things to fool with.

So then Sputnik went up in 1957, I was 11 years old, just about the time you got interested in things, suddenly everyone was supposed to save us from the Soviet Union – scientists and engineers would do that. A lot of opportunities suddenly opened up like summer camps for kids that were interested in science, and by the time I got to high school there were college courses for kids who wanted to do science and math. My parents somehow found out about these things and I got to go. I had no idea, I was just a kid, I had no idea I could actually opt for stuff like that. And now I'm thinking well now I know the whole world is connected, and if you want something you just have to go look for it. In those days the rest of the world was interesting and really far away, we never made long distance phone calls, you never drove anywhere except to the grocery [store] and every year or two we might go to New York, and that was a big scary place. So I spent my childhood reading books and thinking about astronomy, I got lenses and cardboard tubes and made telescopes and all that stuff. It's interesting to try and remember and imagine what it was like because it was so different from today. But anyway, I'm glad you're in it and I bet your stories are just as interesting and different.

Jasmin: I asked John what he would say to students who are thinking of pursuing a STEM career but aren't really sure what direction to take.

John: I think they should have a shot at it because it's exciting to be a participant, you never know how far you are going to get. You said yourself, you didn't catch on to math until last year or something, and suddenly it's fun and interesting and you might actually be good at it after all. A lot of people are sort of buffaloed by the competition– I don't know if you use that word buffaloed in Britain, it means intimidated. **A lot of people are imagining that someone else is talented and I'm not so I'm not going to try. But my view is, sort of the opposite, if you really, really want something, you can probably get a lot further than you are.** I'm never going to play tennis like Roger Federer but I could play tennis more than I do. There's just so many different careers in STEM, I think that is one of the most exciting and interesting things people could be working on, in itself. There are different roles for different people, some people want to go swim with the dolphins, other people want to build submarines and go to the bottom of the ocean and other people want to fly. Other people want to make a microscope that sees inside the cell or make something that sees inside the human brain. To me this is the most exciting time to be in science, and if someone wasn't interested in that I would think they're dead. I don't know if your question was hypothetical or not but I think this is a great time to be a science person or an engineering person because you can build anything now too. I heard a person give a public lecture where he said 'If you can imagine it you can build it' it wasn't so a little while back, it used to be you can imagine that but you can't do it. You can even put things together atom by atom, pick an atom up, move it over put it over there. Pretty shocking huh? Maybe you'll get to design the robot that takes the design of a human being and sends it out to the next star and says when you get there put me together, it's unlikely

Sara: It's a little scary but awesome

John: It is awesome. There are so many things that are happening so quickly.

Maggie: Like 3D printing especially, there are all kinds of techniques now that literally just happened and you can do all kinds of things that you couldn't do before. It's amazing

Sara: And next year you can do even more…

Maggie: Yes there are all kinds of things like surgical parts and 3D printed organs…

John: It's happening as we speak, there is so much that is possible now because of the internet and the communications we now have. High school students can do what the best research lab in the world couldn't do 50 years ago. Genetic engineering, you want to try some, you can do that? So from your school you can continue on and complete your degree in some area of science, physics, math, astronomy, astrobiology, chemistry whatever it is.

I tell people not to necessarily plan too far ahead, because you will find somebody that is really exciting as you did with this physics teacher and suddenly say 'oh that's really what I want to do' and they will be in touch with the most exciting stuff to do right now. And if you try to find out what's exciting by going to the library you can't find out, because it hasn't been written up yet. So I'll listen to podcasts about the latest stuff, I'll walk around and think about the marvels of science every day.

Jasmin: I asked John what he was most looking forward to about James Webb being in operation, and what kind of discoveries we can expect to see?

John: I guess the thing that matters the most is that it works! As for the most amazing science that might come out, I'm just guessing, but I can imagine there's some kind of galaxy out there that nobody has ever seen before. Some people are predicting that they might have existed, this would be the type of galaxy that appeared in the early universe and then they all disappeared, like they were all swallowed up by something bigger – there's some evidence that this happened. But no one has ever seen them directly, maybe we'll see them.

Everything about planets, exoplanets has been a total surprise. The people that predict stuff just missed everything, we don't have nearly enough imagination to know what nature is going to do when it can. That is actually one of the interesting lessons of astronomy, nature is unstable and will spontaneously produce structures limited only by, well not limited by what we can imagine anyway. It's thermodynamically likely to produce complicated stuff, so you probably read about Occam's razor as a way for understanding good explanations of things, but it is misleading is people think that it means nature is simple.

Nature is spontaneously complex, and the reason is pretty fundamental. The universe starts off in a low entropy state at the early universe, it expands and creates entropy by gravitation pulling stuff together. So gravitation produces something called negative specific heat, it means everything is unstable, it means gravitation pulls stars together and heat is released. So where did that come from? We turned

gravitational energy into heat energy, and so it's a self-heating object. In physics class they don't tell you about self-heating objects, there are no such things. You have the law of thermodynamics that say is you have some warmer and something colder when you bring them together they come out to something in the middle, but it's not like that in astronomy. Because it's not like that in astronomy, it's not like that in anything else either because the Earth is not an equilibrium situation, we've got sunshine coming in over here and going out over there, so that sustains life, it's hot on the inside and cold on the outside so we have got convection inside of the Earth, so there's nothing stable and so is spontaneously complex. We can't imagine how complex it is, so that's always exciting.

Maggie: I always like one of the answers you give about one of the great things that will come out of JWST is new questions that we don't even know how to ask right now, that Hubble brought up all of these things we didn't know how to ask and we're building JWST to answer a certain set of questions but it's going to create more questions

John: Yes, and the reason that it always works for astronomy is that nature is complex by nature, and so whatever you find it's going to be more complicated than you ever imagined.

Jasmin: I was really grateful for John to take the time out to talk to me and to the Blueshift team for having me. This is Jasmin Evans, British Blueshift correspondent signing off.

Maggie: Thank you for your report, Jasmin. It was a total delight for us at Blueshift to show Jasmin around Goddard and we know she has a bright future ahead of her. We hope John's words to her are as inspirational to you all as they were to us. That's it for this time.

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