Prof. John Beacom_ Science Is ...g to Memorize What's in a Book

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SPEAKERS

Janet Box-Steffensmeier, Eva Dale, David Staley, John Beacom

E Eva Dale 00:00

From the heart of the Ohio State University on the Oval, this is Voices of Excellence from the College of Arts and Sciences, with your host, David Staley. Voices focuses on the innovative work being done by faculty and staff in the College of Arts and Sciences at The Ohio State University. From departments as wide ranging as art, astronomy, chemistry and biochemistry, physics, emergent materials, mathematics and languages, among many others, the college always has something great happening. Join us to find out what's new now.

J John Beacom 00:31

Thank you, David.

D David Staley 00:31

My guest today is John Beacom, who is the College of Arts and Sciences Distinguished Professor of Physics and Astronomy, the Henry L. Cox Professor of Physics and Astronomy, and Director of the Center for Cosmology and AstroParticle Physics. His research covers a broad range of topics at the intersection of astrophysics, nuclear physics, and particle physics, and he is the lead host of Science Sundays, which we'll learn more about today. Welcome to Voices, Dr. Beacom.

D David Staley 00:36

So, your work is largely in neutrino astrophysics, and I'm interested to learn more about this, but you have to first of all tell us, what are neutrinos?

J John Beacom 01:08

Okay, so I think everybody knows what an electron is. If you stick a fork in the electric outlet, you get lots of electrons. So, imagine electron and just take away almost all of its mass and take away all of its charge, and what you're left with is sort of the ghost of an electron, and that's a neutrino.

D David Staley 01:25

The ghost of an electron is a neutrino, okay. So - and its properties, its...?

J John Beacom 01:29

So, because it has no charge and almost no mass, it barely interacts. So, neutrinos are streaming through us all the time, unlike electrons, electrons more or less stay put. But, for example, the sun is a prodigious source of neutrinos, and in that amount of time, about 100 billion neutrinos went through your eyes.

D David Staley 01:49

Oh, wow, okay.

J John Beacom 01:50

And it doesn't matter which way you're looking, because they're going through the back of your head, too.

D David Staley 01:53

So, how does one capture or otherwise observe neutrinos?

J John Beacom 01:58

So, they're almost impossible to detect, but not totally impossible. And so, you know, just like winning the lottery is really hard, but you can win if you buy all of the tickets. And the way to win is to build a big enough detector that, you know, gazillions of neutrinos are streaming through it all of the time, but very rarely one will interact. So, we're here in Haggerty Hall on the campus of The Ohio State University, this is a very big building. The detectors are about this big.

D David Staley 02:24

About as big as...?

J John Beacom 02:25

Your hands? No, it's as big as the building.

D David Staley 02:26

As big as the building, okay, alright.

J John Beacom 02:28

And the detector is filled - the one I'm talking about now is called Super-Kamiokande, it's in Japan, deep underneath a mountain, it's about as big as this building, and it's filled with the purest water on Earth. And what that does is it reduces radioactive noise that could trick you into thinking something happened. And what you're looking for is - this detector is totally dark, full of ultra pure water, and it's viewed by about 10,000 super sensitive light detectors, and it's just pure darkness waiting for something to happen. A neutrino will come in, totally invisibly, and it'll eventually hit something like an electron. It will scatter the electron, the electron will move, and because the electron will go with the speed of light in vacuum, which is greater than the speed of light in water, it makes a little flash of light, just like a plane when it goes faster than the speed of sound in air makes a sonic boom. And that teeny tiny flash of light will register in the detectors on the walls; that happens about ten times per day in a detector the size of a large campus building.

J John Beacom 02:28

The function of neutrinos, what can you tell us about that?

J John Beacom 02:41

So, you know, our universe is composed of nuclei. So, you know, we're made of carbon, oxygen, nitrogen, iron, all of those things. And those are a mix of protons and neutrons, different mixes of protons and neutrons. And in the Big Bang, the elements that were created were just hydrogen, helium, and lithium - basically, that's it. Where did all of the other elements came from? They were made in stars, and then stars blew up and spilled their guts in the interstellar medium, and then that eventually became new stars and planets and so on. And every time a proton was changed into a neutron, a neutrino was born, or every time a neutron was changed into a proton, a neutrino was born. And gradually, by changing neutrons into protons, you can build up all of the other elements and put them together into nuclei. And so, neutrinos are the signals of those nuclear synthetic processes that made all of the elements necessary for Earth life, everything else.

D David Staley 04:30

Like a byproduct?

J John Beacom 04:32

The byproduct - neutrinos are the non-hazardous waste of all of the nuclear reactions in the cosmos.

D David Staley 04:38

So, why are astronomers interested in neutrinos?

J John Beacom 04:42

Main reason is neutrinos can penetrate through almost anything. We already talked about that, they're going, you know, right through the back of our head, through our eyes, they're going through these detectors; they also can escape the sun in the first place. So, in the core of the Sun, where hydrogen is being fused into helium right now, making new heat atoms that have never existed before, then neutrinos are being made. And, if we can capture those neutrinos, what that lets us do... so, if you're an astronomer, well, if you're anybody, you go out and you look up at the sun - even though your mother told you don't ever stare at the sun - you stare at the sun anyway, what do you see? You see the outside of the sun. But, by catching the neutrinos, what we're seeing is the inside of the sun, the deepest part of the core. And because, by capturing those neutrinos from the core, we're able to measure the central temperature of the sun to about 1% precision. So, you know, I don't know my own weight to 1%, and I don't really want to know, but the central temperature of the Sun is about 15.7 million degrees Celsius, or about double that in Fahrenheit. And we know that as a direct observational fact by capturing neutrinos.

D David Staley 05:48

How did you become interested in neutrinos in the first place?

J John Beacom 05:52

That took a long time, the first thing was to get interested in physics anyway.

D David Staley 05:56

We'll start with that - what drew you into physics, then?

J John Beacom 05:58

When I was a kid, I was always interested in science, but I didn't really have any idea what it was, because I didn't know any researchers, I didn't know academics, I didn't know scientists. And I might never have gotten interested in science if it hadn't been for, you know, rare occasions of seeing amazing things on TV like Carl Sagan's "Cosmos".

D David Staley 06:18

I was a big fan myself.

J John Beacom 06:19

Yeah, that was a mind-blower.

D David Staley 06:20

Yeah.

J John Beacom 06:21

And, you know, occasional events at the science museums and things like that; that planted the seed that made me more interested in science later. And I want to come back to that later, talking about the importance of outreach for catching young minds. You know, through high school it was not really clear that I was destined to be a scientist, I mean, one year I almost flunked out. You know, while all my friends were taking AP classes and calculus, I took auto shop and metal shop. And I mention that because, you know, I run into young people all the time who think, well, if I didn't take calculus and AP Chem II in high school, then I don't have a chance. No, that's not true at all, you can always catch up. It's never too late to get interested in science and to learn the skills. Then, once I got to university, I honestly was not that interested in physics, I didn't really like it. It was just a bunch of hard things to learn. And the thing that changed everything is when I got involved in research, and that went from learning a bunch of facts or trying to learn stuff for a test, to understanding what science is actually about, which is trying to find out new things. Science is not about trying to memorize what's in a book, science is about... the part that makes it fun is trying to learn something new.

D David Staley 07:34

So, what led you ultimately to neutrinos?

J John Beacom 07:38

Well, I like puzzles, and neutrinos are one of the toughest puzzles. So...

D David Staley 07:42

It sounds like it.

J John Beacom 07:43

Yeah, neutrinos require an attention to detail to really small clues and putting together facts that, over a long period of time, eventually tell the story. And I like that.

D David Staley 07:54

So, as I was looking over your biography, one of the things that came across was your interest in multi-messenger astronomy. I'm curious what that is.

J John Beacom 08:02

Okay, so optical astronomy, everybody knows what that is. And then you know, there's radio astronomy, X-ray astronomy, all of that.

D David Staley 08:07

Where you're listening for signals and sounds?

J John Beacom 08:10

Right. So, the two new kids on the block are neutrino astronomy, seeing things that can't be seen with light - like we talked about, you see the inside of the Sun instead of the outside - and the other one is gravitational wave astronomy, where little ripples in the fabric of space time itself can propagate to Earth and can move the detectors a tiny amount, and that can be picked up. For example, there was a merger of two neutron stars, and...

D David Staley 08:36

This was like, in the spring, yes?

J John Beacom 08:39

Well, there's been a few of them because this detector, LIGO, is now up and running. But when this merger happens, there was a tremendous flash across the full electromagnetic spectrum, probably a lot of neutrinos, but it's too far away, we didn't see any neutrinos yet. But, there was a gravitational wave signal that perturbed the fabric of space time, and that ripple traveled to Earth and was picked up in extremely sensitive detectors. And so, the combination of the electromagnetic spectrum and neutrinos and gravitational waves together will give us a much fuller picture of the dynamics of what's going on in the cosmos.

D David Staley 09:13

Tell us a bit more about the Center for Cosmology and AstroParticle Physics.

J John Beacom 09:17

Sure. So, that was founded in 2006 as a part of Ohio State's Targeted Investments In Excellence. It was based on a collaboration between the departments of Physics and Astronomy, and that collaboration was always fruitful, but under the center, so called CCAP, is becoming incredibly more fruitful. We're involved in topics that connect astronomy to physics in essential ways that couldn't be done by either department, and also we're involved in things that connect theory to experiment. So, you know, I'm a theorist, which means, you know, I'm not allowed to touch the equipment, mostly, and, you know, my colleagues who are experimentalists and observers, you know, they build the instruments that are a little bit closer to the action. But together, the theorists dream up new ideas, do calculations, try to synthesize the results from one experiment or another, and together, we come up with something really great.

D David Staley 10:07

Is there a ratio, I suppose, in astronomy between theorists and experimenters?

J John Beacom 10:12

It's not well defined. In astronomy, it's more common that people do a little bit of a mix of both; in physics, for a long time, it's been rigidly separated, theorists and experimentalists stay in your lane. But, we're trying to break that down.

J Janet Box-Steffensmeier 10:27

Did you know that 23 programs in the Ohio State University College of Arts and Sciences are nationally ranked as top 25 programs, with more than ten of them in the top ten? That's why we say the College of Arts and Sciences is the intellectual and academic core of the Ohio State University. Learn more about the college at artsandsciences.osu.edu.

D David Staley 10:53

Tell us what's next for your research.

J John Beacom 10:55

So, one of the things I've been working on is trying to make better measurements of neutrinos from the sun.

D David Staley 11:00

Okay.

J John Beacom 11:01

So, there's a new neutrino detector being built in South Dakota, and it's called DUNE, and they're going to shoot a high energy neutrino beam from Fermilab in Chicago, where there's a particle accelerator, several hundred kilometers across the U.S. to South Dakota, where it will be captured in this huge detector - again, as big as a building. And DUNE is intended to capture these high energy neutrinos from Fermilab and then make exquisite tests of how neutrinos can change from one flavor to another. I didn't tell you, but there are three flavors of neutrino.

D David Staley 11:32

Flavors?

J John Beacom 11:33

Yes. That seemed like a good name, I didn't choose it, but it's a good name. So, the three flavors of neutrinos - the thing about a neutrino is you can start with one kind, and then later, you can have another kind. So, let me give an example. Suppose you sent a fleet of minivans leaving Chicago, then by the time you get to South Dakota, some of them are sports cars and some of them are trucks. So, that would be weird, but neutrinos can basically do exactly that. And so, the job of the detector in South Dakota is to measure those changes. So, our reasoning was, this huge detector could also be used to make exquisite measurements of solar neutrinos. And it's not an intended part of the original plan, but we've shown that it could be possible and how to do it, and we're very excited about that.

D David Staley 12:17

Sounds like it. So, I had mentioned in the introduction that you are the lead host of Science Sundays. First of all, tell us about the series, tell us about Science Sundays and the origin story, I guess.

D David Staley 12:27

Okay, so first, what it is. Science Sundays is the premier outreach event of the College of Arts and Sciences, and it started eight years ago, started by Marty Golubitsky in Math and the Mathematical Biosciences Institute, I'm now the lead host of the series. And what we do is we host eight free public lectures per year, and these cover a wide range of topics in science, all throughout the arts and sciences. We've just finished planning the schedule for the coming year, this will be announced shortly, I can give you some hints of some of the things that are coming. We'll have talks on the mechanics of how hearing works, we'll have talks about the digital initiatives at the Library of Congress, about superconductivity and quantum computing, about food insecurity and mental health, a really wide range of topics. And these start in September, they're once a month. And you're probably wondering, how could I learn more? Well, you could go on the web and go to aol.com, go to the search - oh no, just use Google, and look for Ohio State Science Sundays. There, you can find on the main web page a place to sign up for the once a month email. So, they're held on Sundays in the Ohio Union and there's a nice reception afterwards. And that's formed a really close knit community where a lot of people enjoy coming every month and talking to each other.

D David Staley 13:05

Who constitutes this community?

J John Beacom 13:46

Members of the public, ranging from, you know, retirees to young people, sometimes ten, twelve, something like that. And we ask our speakers to make sure that the talks really reach the public, and that's important. And also, when they're young kids at the shows, we prioritize their question the first.

D David Staley 14:05

Oh, really?

J John Beacom 14:05

Yeah. So -

D David Staley 14:06

That's nice touch.

J John Beacom 14:07

Yeah, anybody under 18, your hand goes up, you get first dibs.

D David Staley 14:11

And so, that's the what of Science Sundays; how about the why, what's the larger purpose, larger goal here?

J John Beacom 14:18

Science is a key element of the human experience, and access to that is a right of everybody. And just having the right is not enough, we need to work to provide access. Science starts with one thing and that's curiosity. Kids have curiosity already, if you don't beat it out of them, it's natural, it's a normal human thing. And curiosity is the starting point of everything. Once you have that, you know, the next step is eventually some knowledge. So, you know, how to do the mathematics, how to operate a flux capacitor, how to use a telescope, things like that. That's technical knowledge that can come with time. But that seed of everything is curiosity, and showing people what can be done peaks that curiosity and drives it. And it's not only for kids, but for lifelong learners. Knowing the facts about science is fun, but that's not why scientists do science. As I talked about earlier, the thing that drives me is research, and the thing that excites the public is learning new things. It's not memorizing a bunch of facts, if you're memorizing a bunch of facts, you shouldn't be in science. And the other thing that science is for is an element of teaching critical thinking, and that's an incredibly important part of our life as a society, not only because it's so technological, I mean, everything around us is technology, everybody should be able to understand some of those things, to not enhance that is crazy. And so, you know, everybody should have those critical thinking skills of a scientist, but that's not the whole story. You know, that's why we have, for example, the College of Arts and Sciences. It's not only the sciences, and part of what you know, scientists need to learn, everybody needs to learn, part of critical thinking is also expression, perception, appreciation for creative processes, and all of those together would make a scientist. And I think we want to show those things to the public. And if we show them just an academic paper, it looks like a pile of facts. They don't see the curiosity that drove it, they don't see the technical skill that went into it, they don't see the critical judgments that went into, how do we choose to do this versus that, how do we figure this out, and so on, and they don't see the creativity of how you just solve those hard problems at all. And that's what we show to the public on Science Sundays.

D David Staley 16:34

I don't have to tell you - we're living in a moment when... well, science is under attack in some ways, there's a lot of forces of anti-science. Is Science Sundays an effort to try to wrestle or deal with that?

J John Beacom 16:45

In a sense, yes. I mean, it's part of a broader effort, not just here, but around the world, for scientists to share what we're doing with the public, because we think it's a right of the public to know what we're doing; not only because of the taxpayers, although that's important, but because scientific ideas pervade all of our life and scientific thinking helps people make good decisions. Critical thinking makes good decisions, and people need that to understand climate change, vaccines, other things like that. And one of the things we've learned is people are not just lacking facts. We've seen lots of cases where people are given facts and they are resistant to them. So, I think the thing that people are missing is the critical thinking skills, and that's one of the most important things that science does. It's not the facts, we can recover... if we lost all of the facts, we could recover them again if we have the tools, the critical thinking tools. That's the main thing we want to teach people how to do.

D David Staley 17:43

So, you had mentioned Carl Sagan, "Cosmos", influential in your own thinking. But I'm curious to know - was that the only source of your interest in sort of this public communication of science?

J John Beacom 17:54

No, that was a big one for getting me interested in science in the first place. My interest in the public communication of science is really about this commitment to access. Science belongs to everybody, and we scientists have a duty to not just say that, but to help bring it to everybody. So, as an example of that, we recently hosted a conference called SciAccess. It was held here at The Ohio Union, and it was led by Anna Voelker, one of the two 2018 Ohio State President's Prize winners for undergraduates, and I was her advisor. And what this conference was designed to do was bring science and the tools of science to people across the whole spectrum of disabilities. How can we make science more accessible to everybody? And so, we brought people together to share best practices, and share new ideas, and to form a community that can advance these ideas. So, we're bringing science to the public through Science Sundays, we're trying to expand access through SciAccess; it's all part of a bigger plan to make science for everybody, because it does belong to everybody.

D David Staley 19:02

And your particular interest in this area?

J John Beacom 19:05

You mean why am I so committed to that?

D David Staley 19:07

Indeed.

J John Beacom 19:08

I think it was important, you know, for getting me into science, and I think, you know, maybe that shapes - that I would just want to open that door for everybody else.

D David Staley 19:16

Well, I'm curious to know how the public communication of science is recognized in your field, by which I am...I'm saying, I note that Oxford University has a professorship in the public understanding of science, and I'm unaware of anything like that in this country. How is, sort of, this public outreach viewed by scientists, not just simply here, but I think across universities?

J John Beacom 19:41

That's a great question. In physics a few decades ago, I think it was largely looked down on. In astronomy, it picked up earlier, partly because of Carl Sagan and others. And astronomy has long been ahead of physics in advancing that and saying that this is a valued part of what we do as a profession.

D David Staley 19:58

Neil deGrasse Tyson is probably a leading public figure.

J John Beacom 20:02

Yes, yeah. And physics is coming around, and we're trying to push that further. So, I think it used to be people said, oh, people who spend their time on outreach aren't real scientists because they're not doing research. Well, that's simply not true. There are many outstanding researchers who are also outstanding outreachers.

D David Staley 20:20

For instance, besides yourself?

J John Beacom 20:21

Well, I mean, just about any of the major figures in astronomy. I mean, I could rattle off a list of names, but - you know, that's part of the culture, that's part of what we do. And we don't do it because, you know, we have to, we do it because we think it's fun and we think it's important. And it's amazing to see that spark in somebody's eyes when they get something for the first time. Maybe you've been to one of those outdoor telescope nights.

D David Staley 20:45

Yes, indeed.

J John Beacom 20:45

And, you know, you show somebody the red spot on Jupiter for the first time. And it's just - it's mind blowing. It's right in front of your face, you just can't see it until you have the tool, and then it just changes the way you think about everything.

D David Staley 20:57

I recall, in high school, the first time I saw Saturn through a telescope. And it was, it was a life changing event.

J John Beacom 21:03

And that is awesome to watch somebody have that experience. It's sort of like, you know, MahĀyĀna Buddhism, that nobody is enlightened until everybody's enlightened.

D David Staley 21:13

Let's talk about what sort of outreach here at home. I'm interested in the sort of classes that you teach, what classes do you teach undergraduate and graduate classes?

J John Beacom 21:21

Okay, so I teach Physics or Astronomy, like, 101, and I teach Physics, like, 9 million. I've never taught anything in between.

D David Staley 21:29

Okay.

J John Beacom 21:30

I like teaching Astronomy and Physics 101, especially physics, because, honestly, most people don't want to be there, and it's a tough room. You know, I walk in, I sometimes say on the first day, okay, I know all of you hate the class, hate the book, hate the homework, don't like me, and don't want to be here: I get it. My goal by the end of the semester is to make you, at least, neutral and, ideally, like the course. And usually about, out of 200 people, I usually turn one person into a Physics major.

D David Staley 21:58

Excellent.

J John Beacom 21:58

And every time I get a free toaster or something.

D David Staley 22:01

It's like detecting a neutrino. And then the upper division, the 9 millions or whatever you described it as.

J John Beacom 22:08

That's just advanced particle astrophysics. And that's more like a practicum, where, you know, it's like a dojo where I'm teaching people how to spar with nature itself on the research techniques. So, not book learning, but practice learning.

D David Staley 22:23

Spar with nature - tell us what that means. It's an interesting phrase.

J John Beacom 22:27

Nature has secrets, and doesn't reveal them easily. But with dedication, we can find them and, you know, sometimes there's some wrestling involved. It feels like a struggle because, you know, sometimes we might think about a problem for weeks, sometimes years before we get the right idea. It's fun, though.

D David Staley 22:47

Well, we look forward to this year's Science Sunday series. John Beacom. Thank you.

J John Beacom 22:51

Thank you, David.

E Eva Dale 22:53

Voices from the Arts and Sciences is produced and recorded at The Ohio State University College of Arts and Sciences Technology Services Studio. Sound engineering by Paul Kotheimer, produced by Doug Dangler. I'm Eva Dale.