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00:44 SC: Welcome to the Science Podcast for October 5th, 2018. I'm Sarah Crespi.

00:50 Meagan Cantwell: And I'm Meagan Cantwell.

00:51 SC: On this week's show, I talk with science writer, Adrian Cho, about mysterious particles zipping through the planet and up through Antarctica, and how that may upset the standard model of physics.

01:03 MC: And I talk to Ben Dalziel about how flu epidemics operate differently in big towns and small towns.

01:12 SC: I'm Sarah Crespi. Adrian Cho is here with me to talk about some physics findings that made headlines this week saying, "Oh, maybe we're gonna overturn the standard model." And Adrian is here to tell us how likely that is, and what the finding was. Hi, Adrian.

01:28 Adrian Cho: Hi, Sarah, how are you?

01:29 SC: I'm good, I'm hoping that you give us a middling hope here that there's some substance to this hype, but maybe we need to control ourselves. Why don't we just start with what was seen?

01:38 AC: The observation is of two unusual cosmic rays, high energy particles from space, that seem to defy explanation by the established theory, which is known as the standard model. These are two observations that were made with a balloon-borne experiment called ANITA, which stands for Antarctic Impulsive Transient Antenna. It's a radio antenna that has so far made four flights around the South Pole. Its primary mission is to look for pulses that are generated when particles called neutrinos, which barely interact with matter, slam into the ice and, once in a great while, they ought to produce a big shower of charged subatomic particles going through the ice that would produce a particular type of radio pulse, and that's the thing that ANITA was looking for.

02:31 SC: But ANITA hasn't seen any neutrinos or neutrino signals.

02:35 AC: But what it does see is signals from other cosmic rays, not neutrinos but from charged particles that strike the atmosphere, and these also can set off a shower of charged particles that goes down.

02:48 SC: And those, so far, have been protons, right? Those are typically protons?

02:52 AC: They're typically protons. Some of them may be light nuclei, and what happens is that that shower of particles bends in the earth magnetic field. That causes it to generate radio waves, and the radio waves typically bounce off the ice and back up to ANITA, and ANITA sees this little pulse of radio waves. And that's how they even know... That's how they detect the shower at all. Sometimes we'll see a shower that's actually coming sideways, from way off on the horizon, from a cosmic ray that hits the atmosphere, and then the pulse comes straight to ANITA; it doesn't have to bounce off the ground. And there's a difference between those two signals. Essentially the ones that bounce off the ground get flipped compared to the ones that come straight to ANITA.

03:35 SC: What about the strange ones? These bizarre observations that we started off talking about.

03:40 AC: From their direction they look like they're coming from the ground, but they don't have this flip in them. And so what that suggests is that there's some sort of particle that's actually coming up all the way through the earth before it makes a shower of particles in the ice and produces a radio waves, and then the radio waves are coming straight up towards ANITA.

04:00 SC: Couldn't these just be neutrinos?

04:03 AC: The neutrino could, in theory, come up all the way through Earth. Once in a great while, one would interact, but the ice would then produce this upward going shower, and you could see that. But from the size of the shower, the scientists know that these particles that would be coming up through the earth would be very, very high energy, something like 700,000 times the energy that's been produced at the biggest particle accelerator so far, and it turns out that the probability that a neutrino would interact in the rock going all the way through Earth goes up with the energy.

04:36 SC: The idea that it would be at this level of energy and coming through the Earth makes it incompatible with it being a neutrino.

04:43 AC: Right. And that's the argument that's made by this team from Penn State University. They're saying that at some high level of confidence, you can't explain these events with standard model particle; you can't explain it with a neutrino.

04:58 SC: Does that mean we need a new particle? Is at the hypothesis, then?

05:02 AC: That's the inference, right? You can't explain these things with ordinary neutrinos, so you might need some sort of new particle and the truth of the matter is that particle physicists have been desperate for some particle beyond...

05:13 SC: They want one so bad.

05:14 AC: Yes, they do, because the standard model is this incredibly self-consistent mathematical framework of all the known particles, but it has these big conceptual holes. It doesn't include gravity, it doesn't include dark matter, there's all these things that it doesn't do.

05:30 SC: What would the characteristics of this particle be based on just these readings, these two readings that ANITA took?

05:35 AC: It would be very heavy, about 500 times the mass of a proton. It would be produced by a very, very high energy cosmic ray hitting the far side of the Earth and this thing would be heavy enough it would basically punch through like a bullet through the Earth. And very, very rarely, it would interact in a way that produces a shower.

05:53 SC: And is that what these particle-desperate physicists are looking for? Something in that size range?

05:58 AC: Yeah, that's the prime target.

06:00 SC: That's great. Okay, well, what about the caveats, the questions that are left over? This was seen twice by ANITA, and then there's also an IceCube observation that might have also seen the same thing.

06:10 AC: Yeah. I guess IceCube, which is this gigantic array of detectors sunk into the South Pole ice that also looks for neutrinos, sees some hint of upward coming events. Although researchers who did this analysis say that it's not strong enough to claim some sort of signal based on IceCube alone.

06:28 SC: Alright, so what are some of the doubts about this? What are some of the open questions?

06:32 AC: Apparently, the sticking point is this whole issue of whether every time a signal reflects off the ice, it gets flipped over the way that this paper assumes that it does because it's the un-flipped nature of these signals that makes...

06:49 SC: Them say it went through.

06:51 AC: Right, exactly. And so that the shower is coming upward. I spoke to one of the ANITA physicists, and he says that that's not a slam dunk. To be sure, he says that he's not exactly sure how you might get this signal flip. But you have to remember, they're looking for very small squiggles, these sort of little bursts of radio waves, that are just a couple of ups and downs, and there's a lot of noise.

07:13 SC: They're not proposing that it flipped twice, so it flipped, and then un-flipped itself?

07:18 AC: There are a number of things that could happen. It's possible that you could have unspecified surface effects that would change this flipping. It's also possible, when the shower itself hits the ice, the radio waves are gonna bounce off the ice, but all those charged particles are also gonna smack into the ice. That will create more radiation. It's possible the two types of radiation could interfere so that you get the wrong polarization of the signal. So, there's at least some concern that this relationship between the polarization of the signal and whether or not the shower was going down or coming up.

07:52 SC: So, Adrian, what do they have to do to shore this up or to disprove it?

07:57 AC: Wow. More events certainly would help. This could be a tricky one because you... Essentially it comes down to how strong is this argument about what happens with the radio waves reflecting off the ice, and that could be a really messy problem. If I had to guess, I would guess that this is gonna be one of those anomalies that hangs on for a long time, and people may never have a super solid answer. I don't think that this will be just dismissed out of hand, but I don't think it's enough to say that they've overturned the standard model.

08:33 SC: Okay. Adrian, thank you so much.

08:35 AC: Sure, my pleasure.

08:36 SC: Adrian Cho is a staff writer for Science. You can find a link to his story at Sciencemag.org/podcast. Stay tuned for an interview with Ben Dalziel about how influenza behaves differently in small towns and big towns, and what humidity has to do with it.

08:55 SC: This week's episode is brought to you in part by Bombas. Thanks to two years of research and development, and multiple improvements in design performance and comfort, Bombas are the most comfortable socks in the history of feet. With an arch support system that provides extra support where you need it most, and a cushion-foot bed that's reinforced for comfort without added bulkiness, Bombas feel like a hug around your foot. Not to mention, Bombas stay-up technology ensures your socks stay in place, so no socks sneaking down your leg, onto your heel, and curling up inside your shoe around your toes. Bombas stay in place without leaving a mark on your leg. And the super soft cotton material makes you never want to take them off. So whether you're a runner, power walker, power lounger, there's a pair of Bombas that'll add comfort to your life. Go to Bombas.com/Sciencemag, and use the code Science Mag for 20% off your first order that's B-O-M-B-A-S dot com slash Science Mag. Code Science Mag, and you'll get 20% off your first order.

10:06 MC: I'm Meagan Cantwell, and I'm with Ben Dalziel to discuss his research on how the size and structure of towns influences the intensity of influenza epidemics. Hey, Ben.

10:16 Ben Dalziel: Hey, Meagan.

10:16 MC: So flu season is just around the corner and given last year's deadly season, people are definitely concerned about how this year is gonna play out. But bad flu seasons don't impact every community equally, though, and some have more explosive spreads than others. What has previous research proposed as factors that influence the duration and size of influenza epidemics in a community?

10:38 BD: There's probably two main factors that drive influenza epidemics, particularly in places like the US, and those are what we call the antigenic evolution of the virus, and then the climate and especially a climate variable called specific humidity. And to understand the first one, the antigenic evolution, you have to understand a little bit about the biology of influenza. So influenza is what we call an immunizing infection, which means that when you get infected with a certain strain of the virus, you're unlikely to be re-infected by that strain again, at least not right away. One of the factors that can lead to a more explosive flu season is when the flu virus is able to successfully switch up some of those proteins and that effectively makes more of the population susceptible, 'cause it's something that fewer people's immune systems have directly seen before. So that's one of the major factors.

11:30 MC: So the flu virus changes and people lose their immunity. How does humidity play a role in this?

11:35 BD: In temperate places like the US, in the winter, as the specific humidity drops the virus is able to remain viable in the air for longer, and that means that there's more connections between people that can spread the virus. So the virus is spread by respiratory droplets that an infected person exhales, and when those are breathed in by someone who's susceptible to the virus, that's what transmits the infection. And so when the virus in the winter in that dry air is able to maintain viability in the air for longer, that connects up the transmission network, you could say; it makes it possible to spread more easily from person to person.

12:09 MC: So with specific humidity, how much longer is the virus viable in the air when it's lower?

12:14 BD: The specific humidity is the ratio of the mass of water to the total mass of a parcel of air. One way of measuring viral viability is in a lab experiment where you spray a bunch of virus-bearing moisture droplets into a drum, and then come back varying amounts of time later, and you do that at different specific humidities. So if you were to come back an hour later in the specific humidity typically associated with winter, you might find something like 80% of the virus still viable. But in conditions associated with summer, that would drop to closer to 50%. And so the time elapsed between when you first put the virus in there, when you come back at different specific humidities, plays into our results in a way because you can think of that time elapsed as the time between when the infected person breathed out those infectious respiratory droplets and when the other person breathed them in. And that's where movement patterns really come into it.

13:03 MC: And some areas with similar climate and strains of the flu virus actually have pretty different intensities when it comes to flu outbreaks. How did you evaluate the underlying driver of these differences?

13:14 BD: We fit a mathematical model to the incidents data. So the model has a number of what we call parameters in it, which are just numbers that express the rates at which different processes happen. And so when you fit the model to different sets of data from different cities, different sets of incidents data, you first of all look at, "Can we get this model to reproduce something that looks like the data in this city?" And so you fit the model to the different cities, and you see, "Yes, we can get these differences reproduced by the model, so perhaps the model is capturing some of the processes that are going on." And then you look at, "Okay, so, model, how did you do that? Which knobs did you turn in order to go from a city with intense flu epidemics to one where they're sort of more spread out?"

13:56 MC: So what did you find was the mechanism driving this difference?

14:00 BD: And we found very clearly that the knob that you need to turn, essentially the single knob that you need to turn, is something called base transmission potential, which is related to how frequently people have close contact with each other. In fact, if you fit the model to different cities and get that base transmission potential, that base transmission potential can actually then be used to predict the population size and, indeed, some of the movement patterns or structure of that city.

14:24 MC: Could you give some examples of cities and small towns that you've compared?

14:27 BD: So I'll say the one that initially kicked off our search for what was driving this was looking at a place like Atlanta versus a place like Miami. Those two places have very different climates. Atlanta tends to have a more spiky flu season that's more focused, and Miami's is more spread out. And so you think, "Okay, maybe that's just because of climate," right? But then you go to a place like Manhattan, very different climate than Miami but with really similar spread out patterns. And so you actually see these spread out, defused epidemic patterns in US metropolises from Manhattan to Los Angeles to Miami, which span like a whole range of climates. And we see indeed the focused, more intense spiky epidemics in some large places like Atlanta but also in small towns all over.

15:12 MC: What kind of characteristics of these cities are different that influence the more diffuse flu transmission versus these spikes that you saw?

15:21 BD: It's at least two things, and the main one is population size. So as cities get larger, their epidemics become more diffused. A lot of things in cities scale with population size, and one of the ones that we found to be associated with influenza intensity was the structure of the city in terms of how workers moved around. And what we show is that as cities get larger, the movement patterns of workers become systematically more highly organized, and this happens in two ways. First of all, more and more people tend to live and work in a few focal locations within the city, so it becomes highly non-random. And the second one is circadian rhythms in movement become more pronounced, so in large cities, there's these pulses into these few focal work locations in the bay, and then back out to the residential areas at night, and those are more pronounced in metropolises.

16:04 MC: So in these areas with varying population size and mobility patterns, does specific humidity then impact flu transmission differently?

16:12 BD: Yes. Our results indicate that in these large, highly organized cities there seems to be potentially more close contact that's essentially making the specific humidity part of influenza transmission matter less, so then the flu is able to spread over a wider range of climatic conditions, and we get theses more spread of epidemics in metropolises.

16:30 MC: What do you think is the next step with this research? What do you wanna expand on that you looked into?

16:36 BD: We'd like to take this to other countries, other cities, see if the predictions of the model are born out there. So that's one, and the other one is to figure out how to bring in genomic data. It's relatively hard to get influenza incidence time series of this quality. In some senses, genomic data on the virus is more available or there's a promising, other data stream, and so figuring out how we could test some of these predictions in that venue would be good and would also move us in the direction of thinking about how we can tie this more closely into developing better vaccination strategies and better vaccines.

17:09 MC: With climate change predicted to increase milder winters, do you think that the transmission patterns will differ in cities versus small towns that have less connectivity?

17:19 BD: It's important to stress that our analysis was not designed to predict what will happen, the flu epidemics under climate change. Indeed, there's a lot of uncertainty about what will happen to specific humidity. It's complicated. It's tied into temperature, for example, in complicated ways. However, our model makes a hypothesis about one dynamic that could play out, which is that, essentially, urbanization and climate may interact in the future to determine the intensity of influenza epidemics. So I think the message from our paper would simply be that urbanization, city size and structure may be another important variable to consider alongside with climate.

17:56 MC: Okay, great. Thank you so much, Ben.

17:58 BD: Thank you.

17:58 MC: Ben Dalziel is a population biologist and assistant professor in the Department of Integrative Biology and Mathematics at Oregon State University. You can find a link to his research at sciencemag.org/podcasts.

[music]

18:13 SC: And that concludes this edition of The Science Podcast.

18:16 MC: If you have any comments or suggestions for the show, write to us at sciencepodcast@aaas.org.

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18:35 MC: This show is produced by Sarah Crespi and Megan Cantwell, and edited by Potogy.

18:39 SC: Jeffrey Cook composed the music.

18:41 MC: On behalf of Science Magazine and its publisher, AAAS, thanks for joining us.