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Clip from Episode 1: Origins of the Universe

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Mysteries of the Origins of the Universe

Orsola de Marco: So, we tend to think that we are things in space. We are a star in space, a person in a room, it's a person in space. But space itself, it's not just a passive emptiness or nothingness. It's actually got presence, and that presence, think of it as full of air. It's not quite it, but imagine there's something in space, and you can send a wave through it, just like you can send a sound wave between me and you, because there is air filling the space between us. It's not quite like that, because air is something in space, but space itself is a thing, and that thing can be pinched, and that pinch will propagate out just like sound propagates out from my mouth to your ear. Now, what can pinch space-time? If I do, if I do, it does actually a little bit, but insignificantly. So, but a big stellar explosion, particularly one that is not spherical, but it's maybe two stars coming together, orbiting faster and faster, and then colliding and merging into one that will definitely pinch space-time and send out a ripple in all dimensions, in three dimensions, and if that ripple gets through you Earth, you can detect it. Not all of them. Some are too weak, but we have now got the technology to detect the strongest ones.

David Christian: And so, these, these, these ripples, can come from very, very early in the history of the Universe?

Orsola de Marco: Yes, they can come from a nearby neutron star merging with another neutron star, or they can come from that very, very early time. And they're not light, they're not electromagnetic radiation, they're completely a different thing. And because of that, they can come from earlier in time compared to this particular time, from which all light, all radiation emerges, which is about 300,000 years after the Big Bang. We were limited to that horizon. But with gravitational waves, we can see much further back in time.

David Christian: So, we're probing closer and closer and closer to the Big Bang?

Orsola de Marco: Yes, now gravitational wave technology to detect them is relatively new. I mean, the LIGO Observatory had been around a long time, but they only successfully found something, got a detection in 2016 so…

David Christian: 2016

Orsola de Marco: Yes, very recent. So, you can imagine the technologies got a ways to go. Back in 2016 it was detection of one or two or three things. Now they actually got a lot better, and we have hundreds of things that blew up and sent a ripple. In the next couple of years, we'll get thousands. So, you can see how things get better. But actually, in order to really see all the types of gravitational waves, in particular the ones we are interested in, the ones that come from very close to Big Bang. You really need to get this technology ship shape. And it's expensive. It takes a long time to figure out exactly how to iron out all the wrinkles.

David Christian: Wonderful. And I think your research on stellar collisions now I think we're moving close to your research, because those stellar collisions can generate, some of them can generate gravitational waves. Can't they? Could you tell me about your research and what links it may have with these issues?

Orsola de Marco: Gladly. So, stars collide. Sometimes they literally collide like a bullet or hit a tree or something like that. But more commonly, they're born together in pairs, sometimes in more than pairs, triplets, quadruplets, quintuplets, and they live their life together, mostly not really caring so much about one another. They orbit one another, but not much happens and their own evolution, expansion, contraction, burning through different stages of nuclear fusion will just happen. But then what happens is, when they get old, they get big, and when they get big, they might get into each other's airspace, and then mass or gas goes from one to the other. And when that happens, all hell breaks loose. And so, you could have all manners of interaction, depending on whether the stars, like the Sun, for example, or could be 100 times the mass of the Sun. It could be a very early star, as in, very old star, born near the beginning of the Universe. It could be a star that's much more recent. Stars have a lot of characteristics, depending on those characteristics, these collisions or merging events are different. The interesting ones that generate detectable gravitational waves—they're the gravitational waves we can see today—are things like neutron stars or black holes. I now said the black hole word, I'll have to explain what it is. I'll come to it. But these stars are actually dead stars. So, a neutron star is a tiny little nugget the size of a large island. When I used to live in New York, we used to say the size of Manhattan. So, they're 10 kilometers across, really small for a star, but they have the mass of the Sun in a tiny little volume. These are basically byproduct of large, massive stars' lives. They are left behind after a big supernova explosion event. And sometimes they are in pairs. So, there's two neutron stars together, and they go around and round in orbit around one another, losing a little bit of energy as it every time they go around. And when eventually they lose enough energy, they basically merge. They come close, close, close, and eventually become one. That event emits detectable gravitational waves. And we've seen them. They actually are amazing, because not only do they detect, not only do they emit gravitational waves, they also emit light. They're called kilonova. They emit incredible bursts of radiation, very beamed, like jets coming out of them. And if you're in the path of the jet, you see it, and it is incredibly powerful. They make all kinds of particles, extremely high energy radiation, and I like to study the radiation, and using the characteristics of what we see, we can try and infer the type of physics that went on. Now, neutron stars are so dense that a spoonful will weigh, hundreds and thousands of kilograms.

David Christian: Sorry, could you say that again?

Orsola de Marco: It's a tiny little bit like a cube of ice, of neutron star will be extremely heavy,

David Christian: My God.

Orsola de Marco: And so high density, we know already if we take a little cube of lead and a cube of wood, the cube of wood doesn't weigh a lot, and the lead does. So, we understand density. So, the lead is denser than the wood, but neutron star material is beyond. Now, when you put that material and compress it in this violent explosion, you can imagine the type of things that happen are really quite beyond what we can test on Earth. So, they're actually amazing laboratories of extreme physics, and that is why we are interested.

David Christian: Because the physics of the Big Bang is seriously extreme physics.

Orsola de Marco: Yes, it is.

David Christian: Fantastic.

Orsola de Marco: So, we basically want, we have lots of theories, including theories of the Big Bang, but we want to test the theories, right? Theories alone are not very interesting. They need to make predictions. And those predictions need to be, coming to pass. So, for example, I say, I if you could measure that, you would find these numbers. And the problem is, many people will say, well, but I can't measure it if I can't make the experiment. So, the Universe, the cosmos, gives us the experimental laboratory to make experiments we can definitely not carry out on Earth.

David Christian: Orsola, I believe that neutron stars play another crucial role in our modern origin story, which is that there are elements that can be created in neutron stars, or when neutron stars collide, that may not be created in other processes. Is that correct?

Orsola de Marco: That is correct. And in fact, stars of different types in different moments of their life create different elements. So even before we talk about the one element everybody wants to ask about in neutron stars, carbon, which is boring and coal-y, actually comes from boring stars like the Sun. You know, normal stars, they get old, and they make most of the carbon in the Universe. Why is carbon important? Because we are a carbon-based life form. It's a relatively abundant it makes lots of nice bonds, so lots of rich chemistry, hence us. Neutron stars make gold and other things, but gold is the one thing we can all relate to. But that is where it comes from. And for the longest time, there was a theory that neutron stars were the site, the place—merging neutron stars—were a site or a place where gold is manufactured. But there wasn't very good evidence, and it wasn't until LIGO, the gravitational wave detector, found a gravitational wave source. Telescopes quickly observed the very same spot. Found the luminous counterpart of the gravitational waves. It was a neutron star merger, and they did observe gold lines in the spectrum of the light. The spectrum is a way to analyze the light and tease out all the information. And so, we had very good corroboration of theory.

David Christian: Fantastic. I didn’t know that. Orsola, thank you very much. You've really given me a sense of the mysteries embedded in the idea of the Big Bang. I mean that the mystery of what was there before there's the mystery of how we can get a better grip on what was happening. And the other mystery that you touched on was this wonderful mystery of whether our brains are so constructed that we will never be able to fully understand the Big Bang.