



— ATHANASSIOS KALIUDIS

## Rediscovering the universe with gravitational waves

**Gravitational waves can be used to find out things about the universe that humanity has not yet had access to. Aidan Brooks measures such gravitational waves - and expects big surprises.**

**Detecting gravitational waves has always required a huge effort and involved tremendous costs. Is it worth it?**

I would say yes, without a doubt! The first detection of gravitational waves in 2015 was a beautiful signal in its own right. One of my friends even had the signal tattooed onto his arm. But the important thing is that we're experiencing the start of an entirely new field of astronomy – one unlike anything we've seen before. It's also worth remembering that relative to other Big Science projects, the cost of the Laser Interferometer Gravitational-Wave Observatory, or LIGO, is quite modest. The International Thermonuclear Experimental Reactor (ITER) and the Large Hadron Collider (LHC), for example, cost over ten billion dollars each. LIGO only cost 1.2 billion dollars, spread over almost 30 years.

**So what do we get for those 1.2 billion dollars?**

We can now start to use gravitational waves to probe high-energy physics regimes that we've never had access to before, such as mergers of black holes or neutron stars. And when you combine that with electromagnetic observations of the universe to create multi-messenger astronomy, the science becomes even richer.

**What do you hope to learn from this research?**

There's a lot of science to be gained from examining the collisions of neutron stars. The pressures and densities of these events are far beyond what we can achieve on Earth. Gravitational waves give us a laboratory to explore physics beyond anything we could hope to achieve on our own planet. Of course, we still want to explore binary black hole systems and their population in the universe. And the question we're asking ourselves is whether there are dark matter candidates lurking in our gravitational wave signals. Could we be on the verge of discovering something completely unexpected? Something



beyond anything we've imagined?

### What do you mean by that?

It seems to be a universal law in science that brand-new technologies inevitably bring new surprises in terms of our understanding of the universe. And it's a relatively safe bet to say that gravitational waves are going to reveal plenty of surprises, both big and small. We've barely scratched the surface yet.

### In 2017 you detected gravitational waves from a merger of neutron stars 130 million light years away. Can you describe how it feels to arrive at work one day and suddenly experience something like that?

"Sudden" is exactly the right way to describe it. There's no warning. You think you're having a normal day and then "bang!" – suddenly there's a signal alert. On that day, I had just arrived at the office. I made myself a coffee and planned, as usual, to check our event database which is normally just a long list of glitches. But suddenly my colleague rushed in and said there was something totally new in there. The signal was at least 20 seconds long – very different to anything we had seen before. At the same time, satellites had detected a large burst of gamma rays. We were all on a massive high for the next 24 hours, but then the news got even better: Our electromagnetic telescope partners had used our rough localization and found the exact source in the sky – a bright new object that hadn't been there days beforehand. Seventy telescopes turned to look at that object – all because of our signal! It was an exhilarating feeling.



Dr. Aidan Brooks is Senior Staff Scientist at the LIGO Laboratory at Caltech—the California Institute of Technology.

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Each day, researchers filter out thousands of interfering signals for the highly sensitive laser interferometer — including their own footsteps.

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### When you look at the curves on your monitor, how do you know what you're actually seeing? The observation of gravitational waves is such an indirect science. Doesn't that make you uneasy?

From a human and emotional perspective, sure. But as scientists we're trained to trust our mathematics. The fact that we can trust our math is key to everything we do – especially when operating far beyond human scales.

### In addition to all the math, what are the essential requirements for detecting gravitational waves?

There's a long list of things you need, but the decisive factor is always stability. Let me give you an example. When the detector – a laser interferometer – is at full power, it has nearly one million watts circulating inside it. Even though we have mirrors with extremely low absorption – less than one photon in every million –, the power absorbed by the mirrors still comes to a few hundred milliwatts. The pressure from the photons and the thermal expansion of the glass create very weak lens effects in our optics. When I say weak, I mean a focal length of tens of kilometers, but it's still enough to create major problems for our detectors!

### How do you counter that problem?

We project CO2 laser beams onto the optics. The beams are precisely shaped to create a negative lens and remove this time-



