It's the Spinning Before the Crash that Makes the Waves

"*If two neutron stars collide in a distant galaxy, and no one can detect it, does it make a gravity wave?*"

That's not just a clever twist on an old philosophical thought, but a real physics question, first hypothesized (admittedly with a little less mysticism) by a scientist in the early 1900s. At least the existence of gravity waves was hypothesized. They didn't know about neutron stars yet.

This particular true story started one hundred and thirty million years ago, give or take, in a typical galaxy, not so far away. Two neutron stars got too close. Though each star had a diameter of just 20 kilometers (12 miles) or so, their individual masses were from 1.1 to 1.6 times the mass of the sun. The stars whirled around each other at hundreds of revolutions per second.

The frantic spinning of such massively dense and heavy objects created intense gravity waves that spiraled outward at the speed of light, literally disrupting space and time as they rippled out into the galaxy and then the universe.

Then the stars finally merged into violence a very bright light...with an afterglow that stayed a while.

What the Dinosaurs Never Knew

Not far from the colliding neutron stars, as distances in this universe go, there was a smallish planet circling an ordinary sun in the outskirts of a plain medium galaxy. If looked at from its only moon, just a couple hundred thousand miles away, the little planet appeared as a bright blue and white marble. At the time of the merging, the planet was probably dominated, as it still is, by microbes, viruses, and possibly ants. But a size-prejudiced observer might have concluded that the large dinosaurs walking on its surface were in charge.

Those merging neutron stars gave off a heck of a bright light. When the dinosaurs looked up to the sky, they saw ... nothing. Because "not far" in this universe was still 130 million light years away. It would take 130 million years for the light and gravity waves from that event to reach their beautiful little blue and white world.

The dinosaurs were unconcerned with the collision of two collapsed neutron stars and the resulting gravity waves. Nor should they have been. By the time those once frighteningly disruptive waves would reach earth, in the incomprehensibly distant future, the space-time distortion they would create would be imperceptibly small—thousands of times smaller than the nucleus of an atom. Nothing alive could possibly notice.

Deleted: admitedly

Commented [AW1]: These two sentences are a bit confusing. Maybe turning them into one sentence with a dash between "hypothesized" and "they" would make them clearer.

Deleted: '

Commented [AW2]: Consider: "Due to the extreme gravitational attraction between the stars, they whirled ...

Commented [AW3]: Needs to be rewritten. Consider: "violently, producing a very bright light. OR giving off a very bright light

Deleted: nd

Deleted: .

Deleted: .

Commented [AW4]: Consider: lasted quite a while

Formatted: Highlight

Commented [AW5]: AP Style guide's rule for ellipses is space dot dot dot space

Commented [AW6]: "not concerned" flows into "Nor" better

Deleted: - t

The probability of any life-forms on that planet ever knowing about, or comprehending, the massive cosmic events taking place at distances beyond imagination was too small to calculate. Like all the waves before them, these would surely pass unnoticed.

But life kept changing. There were massive extinctions. Life recovered and diversified again, and again, and then again. Eventually, in the very recent past of the blue planet's life span, a medium-sized primate left the trees and began to walk on two legs. Much more time passed, and the primate grew and changed. They became tailless apes walking persistently upright on their two hind legs. And on the other two appendages? Some really marvelous and useful hands. What to do with those?

Hands, Brains, and Imagination

How about turning them into tools that, coupled with a large complex brain capable of imagining and questioning and creating like no other known life-form, could be used to create other tools? So they did. Through a combination of trial and error, serendipity, and imagination, they made more and more useful things. They learned to work together—well, most of the time. They also fought a lot. But when they did work together, it was astonishing what they could accomplish.

Centuries passed. They kept making better and more productive tools, art and music for pleasure and growth, and, of course, weapons for hunting, self-protection, and doing unto others what they would not have done to themselves.

Those productive tools meant that one clever two-legged, two-handed ape could now do the work that had taken many to do before. This allowed for specialization and diversity of labor. Many clever apes were freed to spend most of their time on specialty tasks not tied to immediate survival. At first these specialists were priests, craftsmen, bosses, and administrators. Then there were lawyers, talk show hosts, realtors, and most important, at least for this article, scientists and engineers.

Civilization was born, and they called themselves human.

How to Get Out of a Rut

Thousands of years of civilization passed. Yet, for all their busy history and cleverness, the humans were stuck in a thinking rut. They were just making up stuff. Stuff to explain physical, biological, and social phenomena and processes. Sometimes it was imaginative, clever, even charming, but it was still almost all wrong.

Strangely, no matter how obviously wrong or unhelpful the made-up stories often were, the humans felt that once they had a story, they had to, no MUST, stick to it—as well as make everyone else stick to it. Those that dared to think differently, or even question, were often treated quite badly.

Commented [AW7]: Consider: let alone

Deleted:

Deleted: passed

Commented [AW8]: Confusing with the last use of "on" in the preceding sentence. Consider "And those things at the ends of the other two appendages?"

Commented [AW9]: "them" is better

Commented [AW10]: Should a question mark go here?

Commented [AW11]: Might flow better with "And that's what they did" Or

Deleted: .

Deleted: - w

Commented [AW12]: "as" would seque with the alliteration a little better

Commented [AW13]: A little awkward. Maybe just "work of many." or "could now be as productive as many of her ancestors."

Commented [AW14]: Do you mean "division"? Not sure which is better.

Commented [AW15]: Consider deleting

Commented [AW16]: Consider: "stuff up"

Deleted:

Deleted: - a

Cosmically speaking, the gravity waves were now extremely close. They had traveled over 99.9999% of their journey. It was still a sure bet that they, like all the others, would pass through the blue planet's solar system without detection.

Then, just a fraction of a fraction of a moment in the gravity waves' life spans, there was an unlikely moment of enlightenment. It might be more accurate to say a moment of just plain old common sense. Some humans in certain places started to open their minds and think outside the "make-stuff-up" and "I'm-sticking-to-it" box. This astonishing and unlikely period in human history came to be called the Renaissance. I say it was unlikely, because given the human propensity for literally hating story changers, it was extremely difficult, and usually dangerous, for these thought pioneers to change other human minds. Even with test data that *proved the made-up stories wrong*!!

Commented [AW17]: Just used "moment"; consider here "era" or "time". Or maybe edit the other phrase: "a fraction of a fraction of the gravity waves' life spans"

Deleted: ,

Commented [AW18]: Maybe these are two boxes?

Go with the Proven Facts

Early thinkers and experimenters named William Gilbert, Galileo Galilei, and Robert Hooke, were the first to clearly state it: "Don't make up stories, then imagine or insist that reality fits those stories, ignoring, even suppressing, anything that contradicts your stories. Make a shrewd assumption based on logic, reason, data, honest open-minded observations, and known facts. Then test it. If the data ***repeatedly*** verifies your assumptions, then you may have found something useful. You can maybe even call it a fact or a truth if the data, verified by others over time, continues to verify it."

Commented [AW19]: A little confusing to name these people and then use quotes. One thinks, "did they say this?" maybe just put the quoted material (minus the quotes" as a new paragraph

Commented [AW20]: Might be clearer to use quotes here: a 'fact' or a 'truth' if …

If the test data doesn't verify, then move on. Get over it. It's no skin off anybody's nose. Chill out. Nobody needs to be killed over it.

Even more wondrous, and relaxing, if new data and information comes along, ***you are allowed to learn from it and even to change your mind***! Isn't that cool?

Still, it wasn't easy. Such a simple, logical, and seemingly non-threatening thinking method was a hard pill for much of humanity to swallow (and still seems to be for many). But the practitioners of this new way of learning, who came to call themselves "scientists", courageously persevered.

Decade after decade they kept learning. Step by step, they built on what other inquisitive, persistent, brave, scientists had learned before them. Sometimes they were penalized, imprisoned, even killed, for finding out things that seemed to disagree with the made-up stories. [this account overlooks the dogmatisms that scientists themselves succumb to; particularly applied scientists studying complex systems, like those who reasoned from "I can't figure out why there should be a difference between butter and hydrogenated oil to "there's no reason to suppose there's a difference between butter and hydrogenated oil. Examples from nutritional and medical science abound.]

Within 150 years of the gravity waves' arrival, there was no longer any doubt concerning the power of the scientific method. Marvels of human engineering and science that were previously inconceivable, and often seemed miraculous, became commonplace.

"*The questioning explorers also started looking inward, inside their own bodies...smallpox, perhaps the most deadly and terrifying disease in human history, was eliminated from the planet.*"

"*When we use unbiased, scientific reasoning, work together across national borders, setting aside petty differences, it's astonishing what we two-legged upright humans can accomplish.*"

There's Truth in Small Things Too

The questioning explorers also started looking inward, inside their own bodies (which could also be dangerous back then), and even into the micro-world of exceedingly small microbes and even smaller viruses. With the knowledge acquired by simple scientific thinking and clever experiments they figured out how to make a vaccine that would train the body's immune system to defeat some very dangerous viruses.

Deleted: vacine

Smallpox, perhaps the deadliest and most terrifying disease in human history, was eliminated from the planet. Then came polio, the most feared disease of the first half of the 20th century. It is very close to being eliminated on this planet. Less frightening, but still dangerous, viral infections like chickenpox, mumps, and measles have also been nearly eradicated. Elimination is being slowed by misinformed and gullible humans who still seem to prefer stories, mistruths, and superstition, over lifesaving vaccines. Go figure.

Deleted: life saving

But the wave was getting very close, and still no one suspected the existence of gravity waves.

Matter and Energy - Two Sides of the Same Coin

Then, just a little more than a century before the wave arrived, a young scientist working in a patent office published some thoughts and equations that shook the world. In a couple of little scientific papers, he predicted, among other things, that the speed of light is a universal constant and that matter can be converted to energy according to the formula E=mc^2. The E is a quantity of energy equal to a quantity of mass times the speed of light squared. Talk about something that was, and still is, hard to get your mind around. That was a mind blower. Matter and energy are interchangeable and the conversion factor is the speed of light?

Commented [AW21]: I think it would be clearer to say, "Here 'E' stands for the amount of energy equal to a mass ('m') times the speed of light ('c') squared.

The young physicist, named Albert Einstein, also predicted the existence of gravity waves. He predicted them but thought they would probably be far too faint for human-made instruments to ever detect or measure.

Deleted: ,

Formatted: Highlight

Deleted:

Nevertheless, scientists kept plugging and science continued to advance. Countless experiments, conducted on more and more sophisticated instruments, verified again and again the accuracy of Einstein's predictions concerning the nature of energy, mass, light, gravity, and its effect on space-time.

Commented [AW22]: Consider "their effects".

Scientists and engineers also exploded some really big bombs that demonstrated noticeably the truth of Einstein's formulas. Any lay person, no matter how resistant to new knowledge, could understand that bit of data.

Still, as Einstein had speculated, the gravity waves remained elusive.

How to do It

Gravity waves really do distort what is often called the space-time continuum, or just space-time. The lengths of physical objects change when a gravity wave passes through them. Therefore, all you have to do to detect such a wave is somehow notice and measure a change in space-time.

Yes, that sounds hard. It's further complicated by the vastness of the universe. Gravity waves arriving at Earth after traveling millions or billions of light years are very small and faint. How faint? Well, let's say you could build two 4-kilometer-long tubes, each containing an almost perfect vacuum. Connect the tubes at one end at a 90 degree angle—an L-shape, if you will. Fire a laser beam into a beam splitter that divides the beam into two beams, one traveling down each tube. At the other end of each tube you would hang an exquisitely precisely placed mirror to reflect the beams back to the source.

Along comes a gravity wave that passes through the beams. True to the nature of a gravity wave, each beam is actually stretched a little bit. How little of a bit? The beam's length would increase by 1/10,000th of the diameter of a proton! And the length change of each of the two beams would occur within 10 milliseconds of each other. If you could detect that, you would know that you had probably found a gravity wave.

Is that even possible? Now you know why Einstein suspected that scientists might find that hard to do.

But those tenacious scientists kept learning and imagining. Just a few decades before the arrival of the gravity wave described at the beginning of this article, they conceived of that 4-kilometer tube with the laser beam. Just a few years before it's arrival, they had completed several of them.

They are engineering and scientific marvels, and they worked. Before our gravity waves arrived they had detected other gravity wave events. But not from neutron stars, these were from black hole collisions, even further away.

Important Interlude:
As you may have guessed by now, this isn't really a story about neutron stars or gravity waves. It is story about human growth and the power of the scientific method. When we use unbiased, scientific reasoning, work together across national borders, setting aside petty differences, it's astonishing what we two-legged upright apes can accomplish.

Deleted: A

Commented [AW23]: Consider deleting

Deleted: , a

Commented [AW24]: A little confusing from "Well, let's say … " to the end. Due to flipping between subjunctive and imperative cases. Consider at least changing this to "each tube hang an exquisitely .. "

Commented [AW25]: Not correct with a comma. Consider a semicolon or a dash

Commented [AW26]: Series is not quite grammatically correct. Consider "and set aside petty differences"

At the end of this page, I provide some links to learn more about LIGO, neutron stars, gravity waves, and in particular the neutron star collision that inspired this true story. You shall visit them!

And now to conclude this epic adventure:

When the gravity waves from the neutron star collision of 130 million years ago reached the small blue planet, the gravity wave detectors, against all probability, were waiting.

Three specific instruments and the scientists that operate them, working together, are the heroes of this amazing true story. Two of the instruments are in the United States. They are both designated as a “Laser Interferometer Gravitational Wave Observatory”, or LIGO for short. One LIGO is in Hanford, Washington. The other is in Livingston, Louisiana. The third instrument, named Virgo, is near Pisa, Italy.

Now follow in real time:
August 17, 2017, 8:41 am, Eastern Daylight Time: The two United States LIGO instruments detect a gravity wave signal that ripples through their detectors for around 100 seconds. The Fermi space telescope detects a gamma ray burst 1.7 seconds later. Virgo in Italy also detects the gamma rays. The LIGO events are fractions of seconds apart. Using the tiny differences in detection times the scientists are able to pinpoint a section of sky from where the signal came. Ninety observatories all over the world are alerted. Their telescopes are turned toward the predicted region, and they see … **a new light in the sky**!

Against All Odds, We Did It

No observant being watching the upright walkers for most of their existence, would have bet a pebble that they would ever have imagined the existence of, and then built an instrument to detect, that wave.

Much was discovered from the data collected and still being analyzed by the observatories all over the world and in space. Unexpected things were learned. Past theories were proved and others disproved.

We learned that neutron collisions are one of the ways that gold, platinum, and other heavy metals are created. This had been theorized, but not proven until this event. Yup, I'm pondering my gold wedding band. It came from a neutron star collision, or similar cataclysmic event far away and long ago.

We now know that at least one source of those, once mysterious, short gamma ray bursts is colliding neutron stars. Again, previously theorized, but not known for sure.

The list of new knowledge is long and getting longer. The provided links will help curious learners find out more.

Commented [AW27]: Consider deleting.

Commented [AW28]: In North America, “proven” and “disproven” are more commonly used here. And you use “proven” below, so that conjugation should be used here too.

Deleted: collisons

When we team together, calmly, thoughtfully, asking questions, and finding ways to test and answer those questions, without bogging our brains with made-up untested stories, it's astonishing what we can achieve.

Learn more about gravity waves, neutron stars, LIGO and what we're learning there from the following links:

Deleted: thoughfully