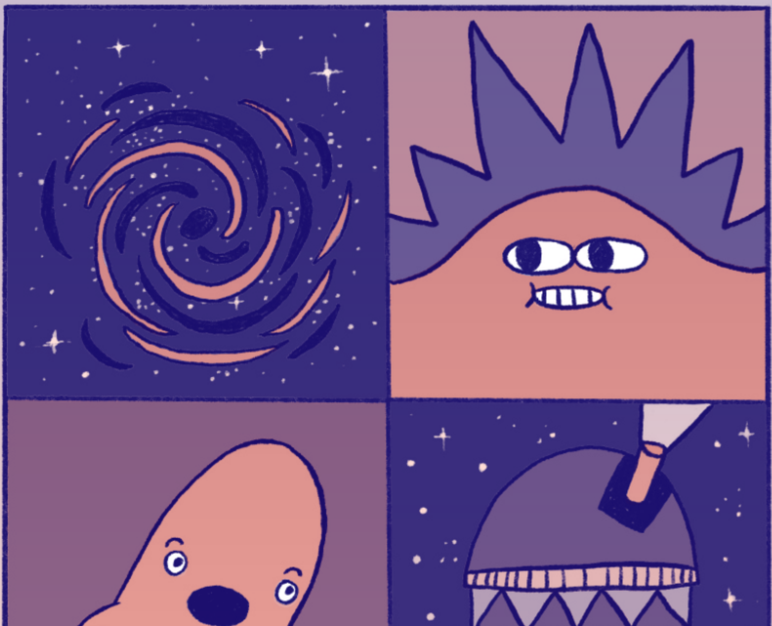
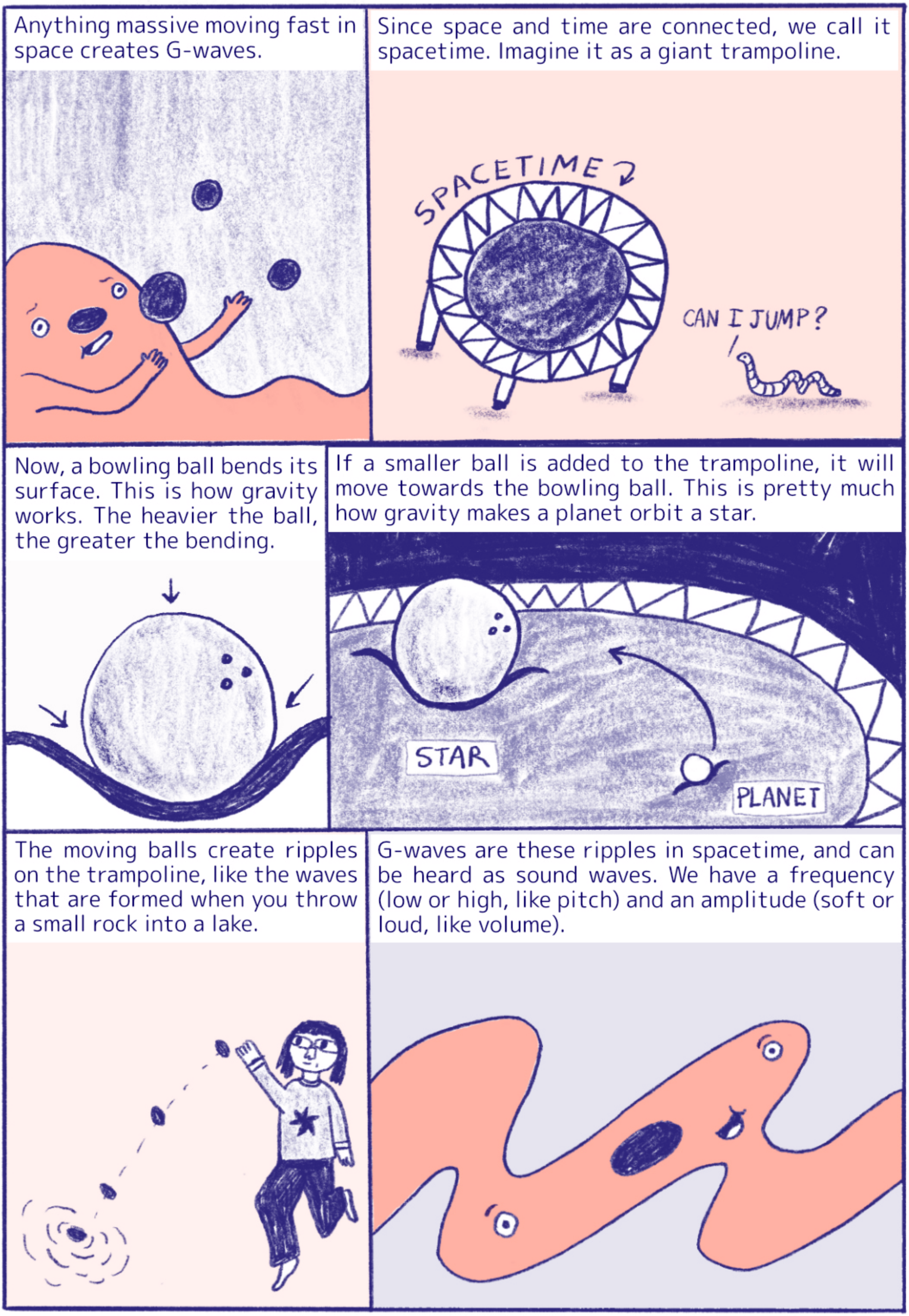
COSMIC



WAVES

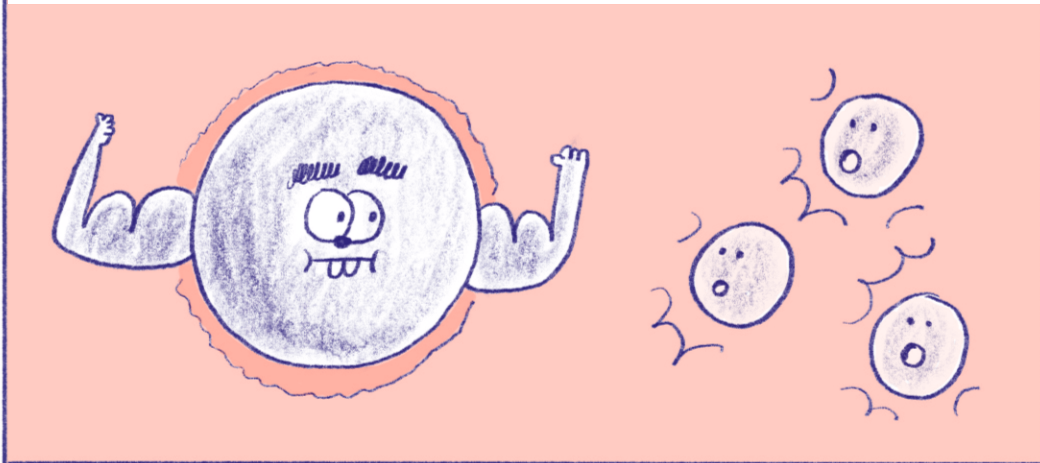

Nobody can see or touch me...
I'm not alive like you or a worm...
Hi.
But I travel through the Universe and carry its secrets.
I'm a gravitational wave! You can call me G-wave for short.
It took me more than a billion years to get to Earth, and scientists spent years building detectors to find me. Let me tell you my story...


Anything massive moving fast in space creates G-waves.
Since space and time are connected, we call it spacetime. Imagine it as a giant trampoline.
SPACETIME
CAN I JUMP?
Now, a bowling ball bends its surface. This is how gravity works. The heavier the ball, the greater the bending.
If a smaller ball is added to the trampoline, it will move towards the bowling ball. This is pretty much how gravity makes a planet orbit a star.
STAR
PLANET
The moving balls create ripples on the trampoline, like the waves that are formed when you throw a small rock into a lake.
G-waves are these ripples in spacetime, and can be heard as sound waves. We have a frequency (low or high, like pitch) and an amplitude (soft or loud, like volume).


But we're not like the waves at your favorite beach...
See, I'm very very very tiny
10.000 times smaller than an atom.
I'm so tiny and difficult to find that, although physicist Albert Einstein predicted my existence, he still had some doubts...
IT'S VERY UNLIKELY THAT WE WILL FIND GRAVITATIONAL WAVES!
The only hope was to wait for a massive event in our Universe
and build a super precise type of ruler to detect us G-waves...
YOU NEED TO DO BETTER THAN THIS!
Not so easy, huh?

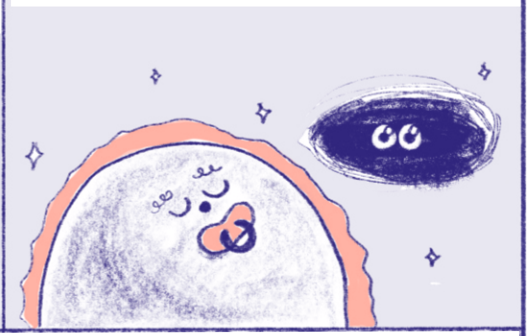

But, then, what would be this "massive event"?
Well, it started long ago, when two stars
got a bit too close.
Gravity made them dance around each other, creating ripples in spacetime...
Until they eventually collided. It was a really massive event, and I was born!

Now, these weren't just any stars... They were neutron stars!

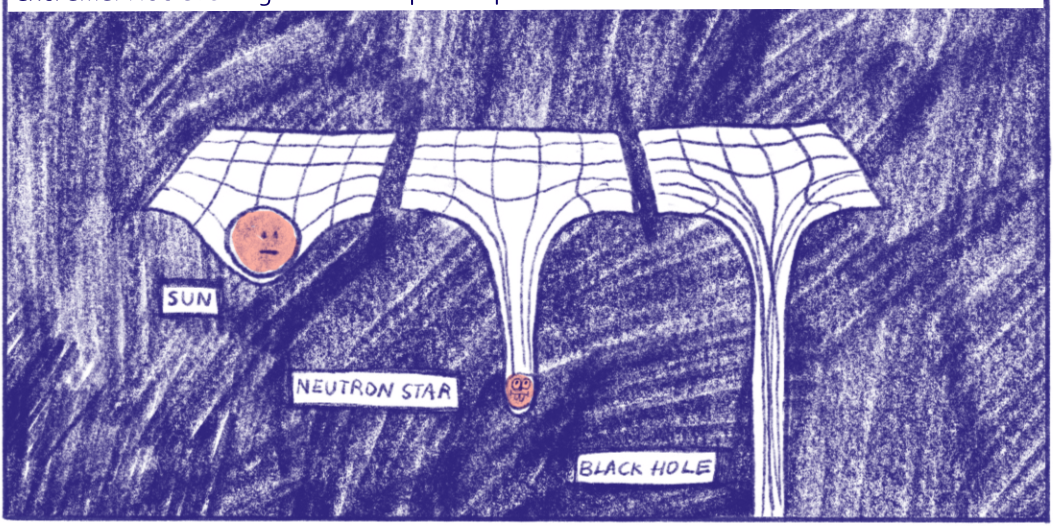


At the end of a supergiant star's life, all of its fuel burns out, and a big explosion, called a *supernova*, happens.

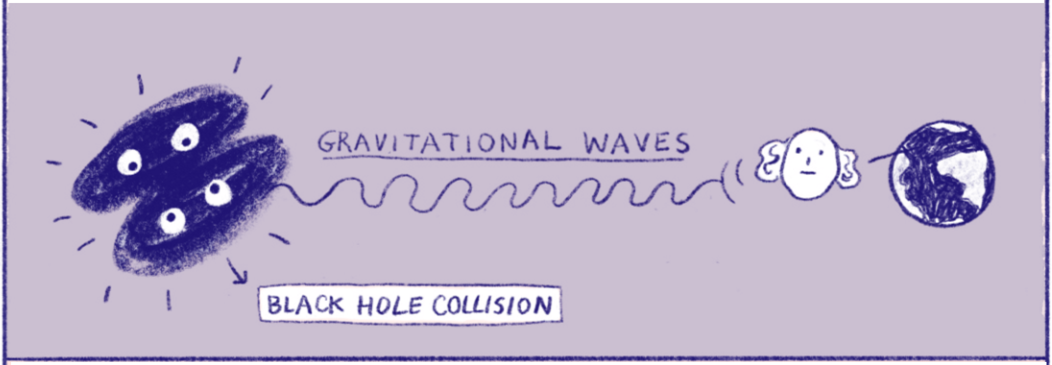
From this explosion, neutron stars and black holes can be born.



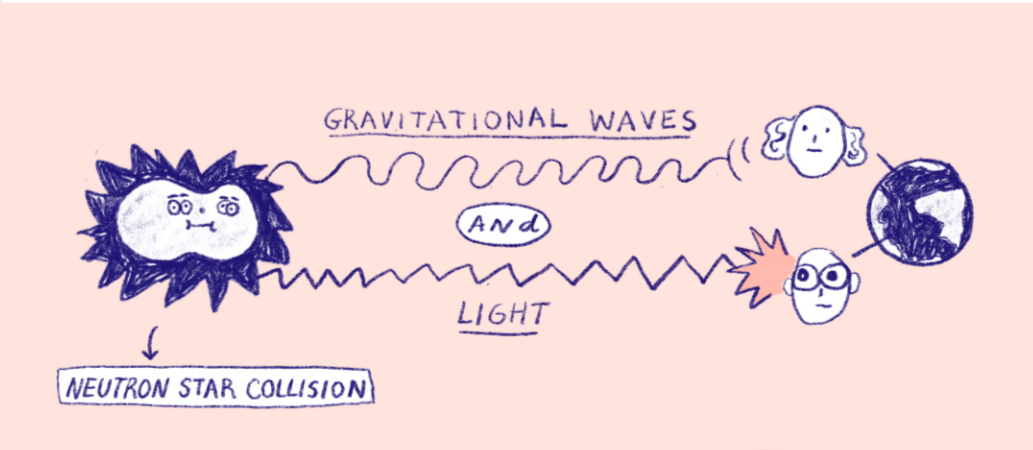
Neutron stars and black holes don't need to be big to be powerful. They have such a dense mass that their gravitational effect (or their power to bend spacetime) is very extreme. Not even light can escape the pull of a black hole!



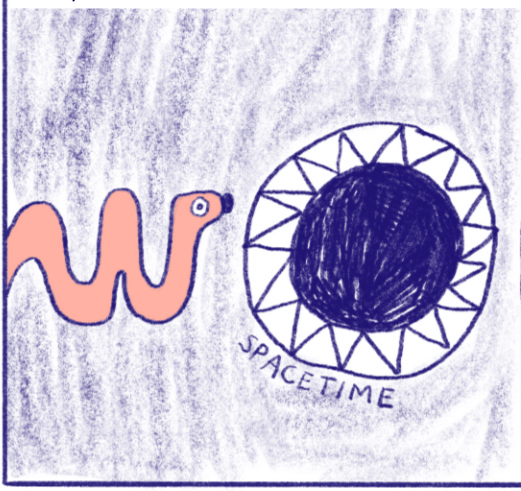
That is why, when black holes collide, scientists only hear us G-waves. They can't actually see any light from the collision, and call this type of event *dark sirens*.



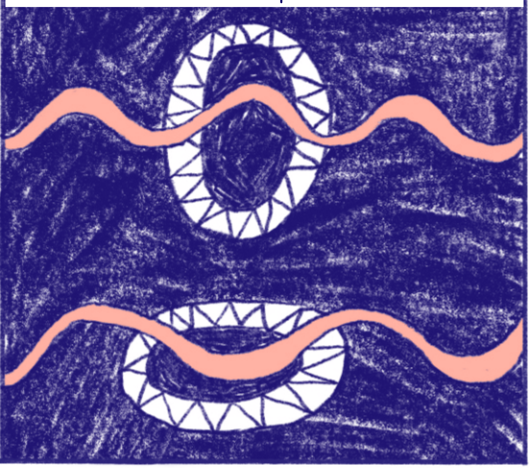
When neutron stars collide, something special happens: a *bright siren*! This means their collision produces both G-waves and a burst of light that telescopes can see.

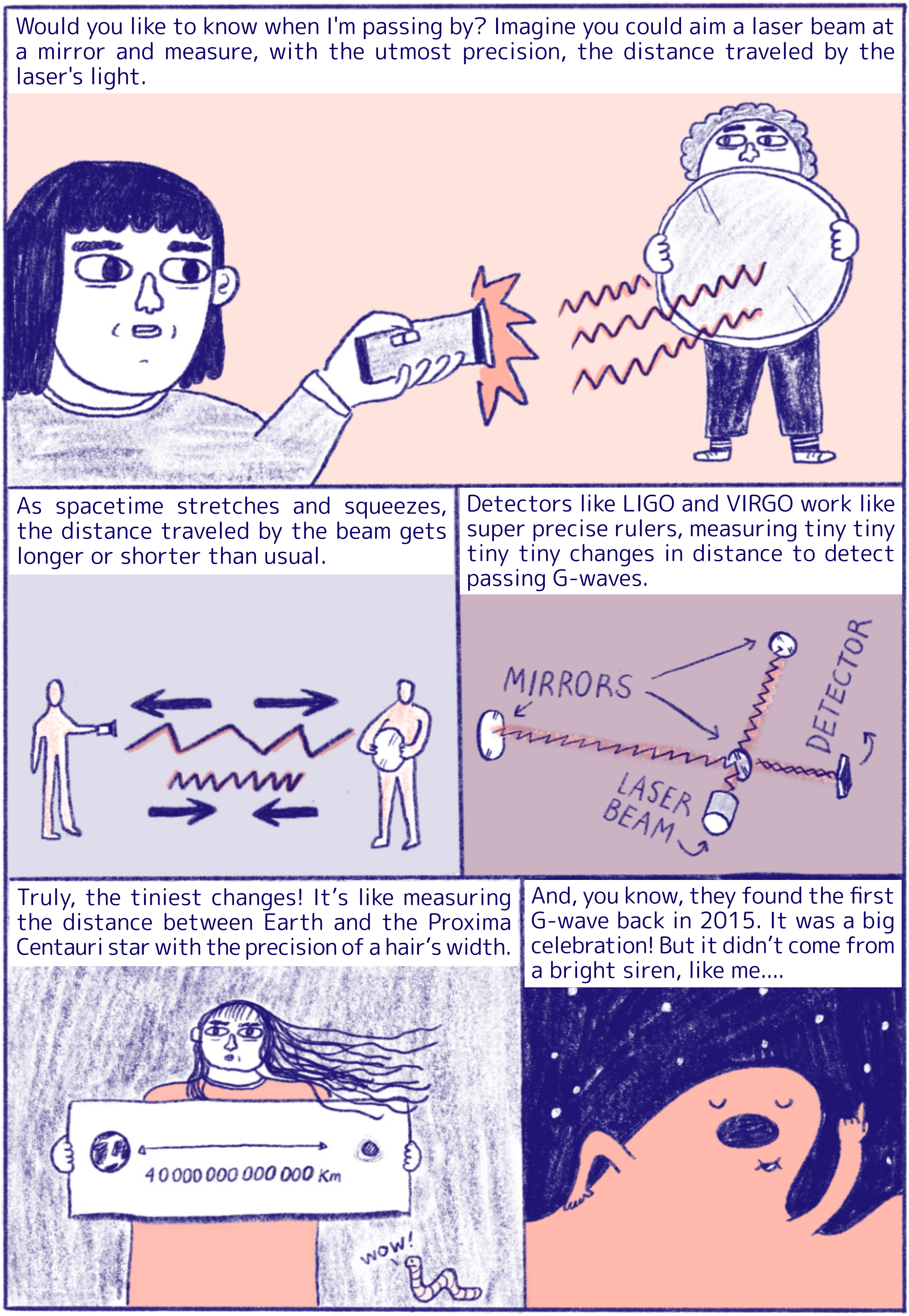


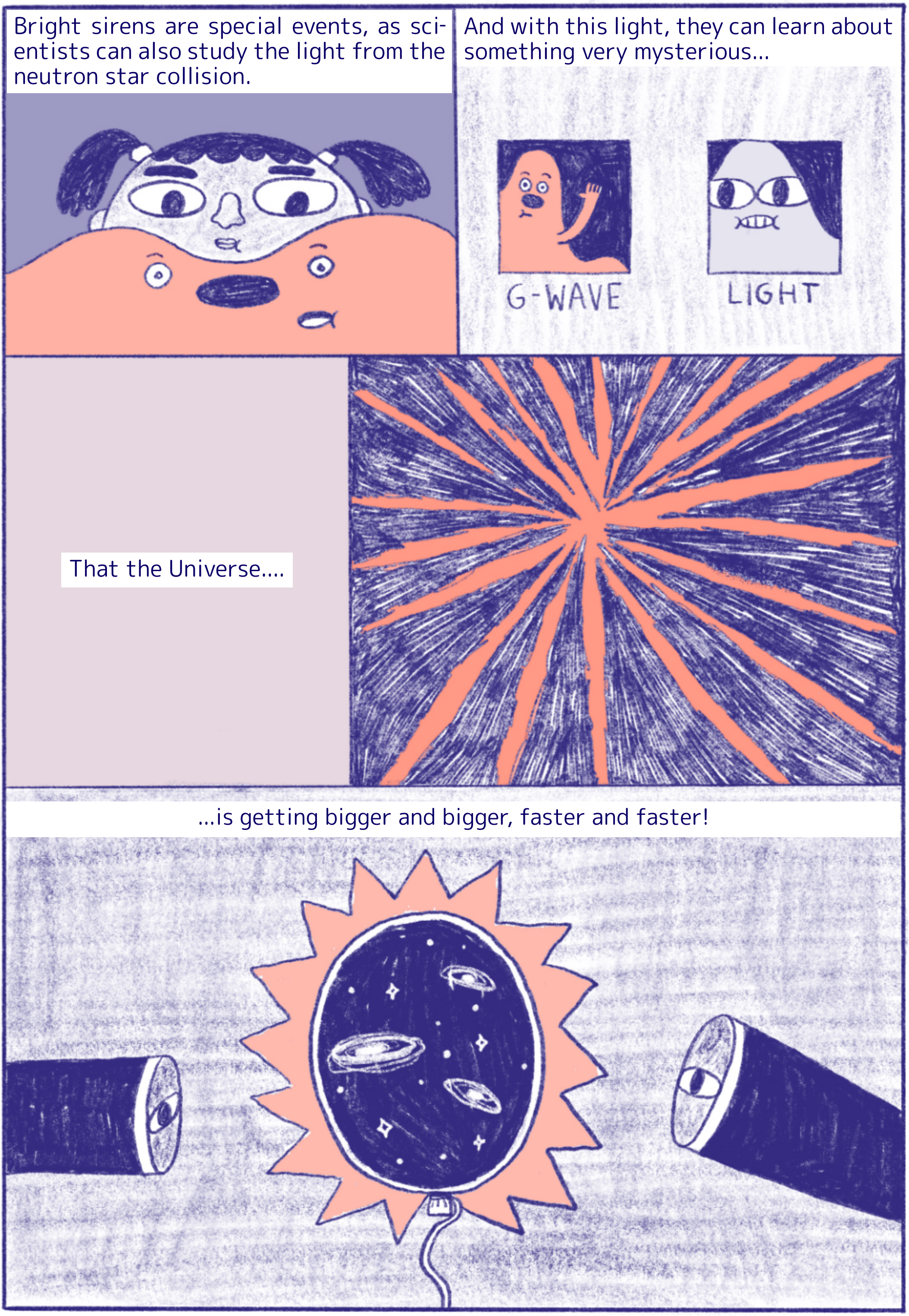
Detectors like LIGO and VIRGO are specially made to hear G-waves.



The idea behind these detectors is that, since I'm a ripple, when I wriggle, spacetime stretches and squeezes.

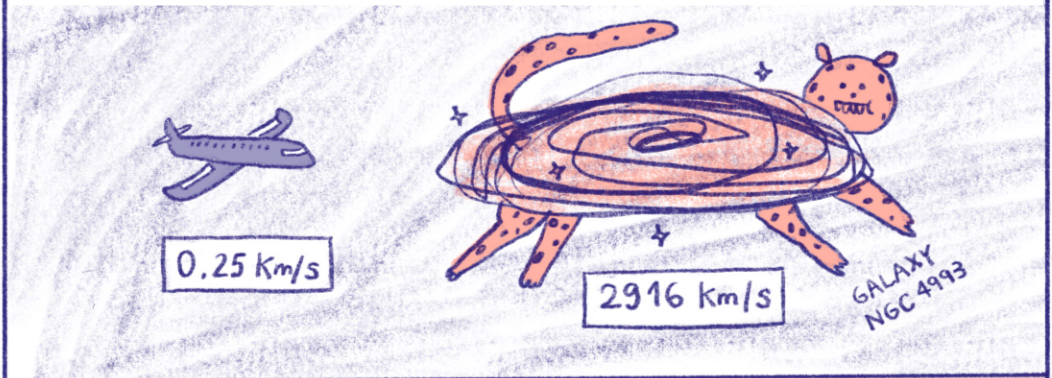



Would you like to know when I'm passing by? Imagine you could aim a laser beam at a mirror and measure, with the utmost precision, the distance traveled by the laser's light.
As spacetime stretches and squeezes, the distance traveled by the beam gets longer or shorter than usual.
Detectors like LIGO and VIRGO work like super precise rulers, measuring tiny tiny tiny tiny changes in distance to detect passing G-waves.
MIRRORS
DETECTOR
LASER BEAM
Truly, the tiniest changes! It's like measuring the distance between Earth and the Proxima Centauri star with the precision of a hair's width.
40 000 000 000 000 Km
WOW!
And, you know, they found the first G-wave back in 2015. It was a big celebration! But it didn't come from a bright siren, like me....

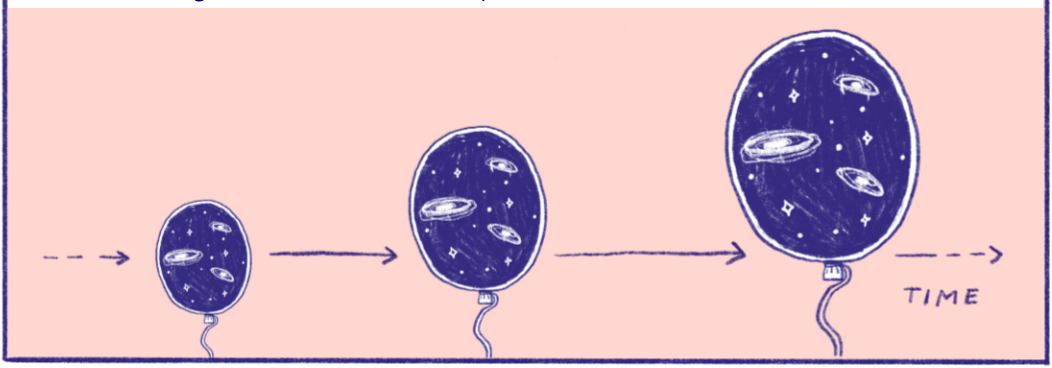

Bright sirens are special events, as scientists can also study the light from the neutron star collision.
And with this light, they can learn about something very mysterious...
G-WAVE
LIGHT
That the Universe....
...is getting bigger and bigger, faster and faster!

Imagine the Universe is a balloon with a few stars drawn on it. When you blow up the balloon, the stars move further apart (next birthday party, remember to try it, ok?). By measuring the distance between stars or galaxies over time, scientists discovered that they are moving apart, so the Universe is expanding.

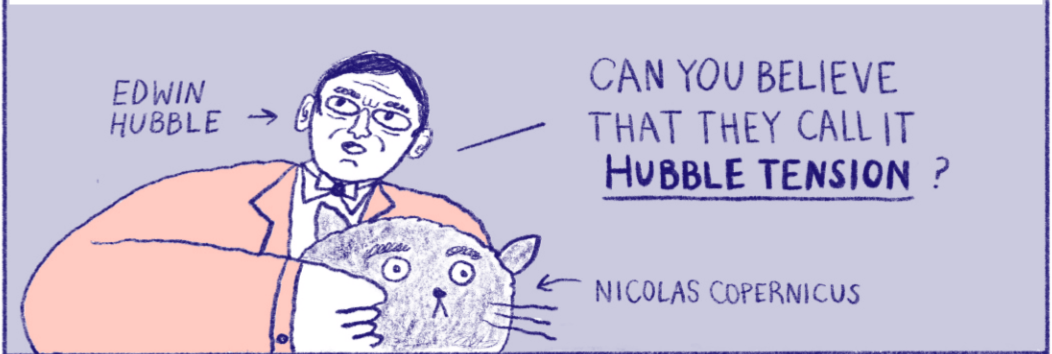
I was born in the galaxy NGC 4993, and since astronomers saw the light from the collision, they could also measure how fast the galaxy was moving.



You know, when scientists figure out the distance and speed of a galaxy... Boom! They can calculate how fast the Universe is expanding. But it's not that easy, my friend. Nothing in the Universe is easy.

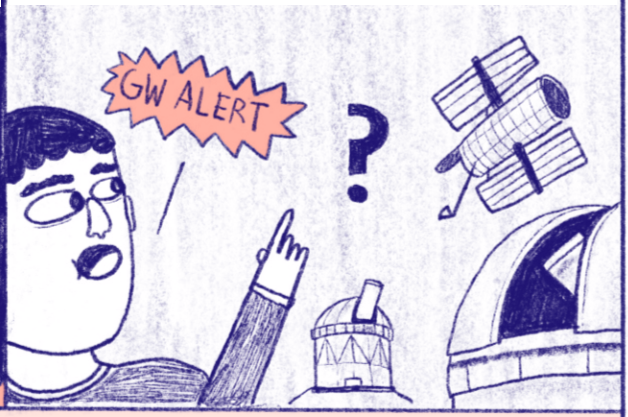


Around 100 years ago, E. Hubble discovered that the Universe is expanding. Since then, scientists have been trying to find out exactly how fast this is happening. But the results always seem to be... a bit different.

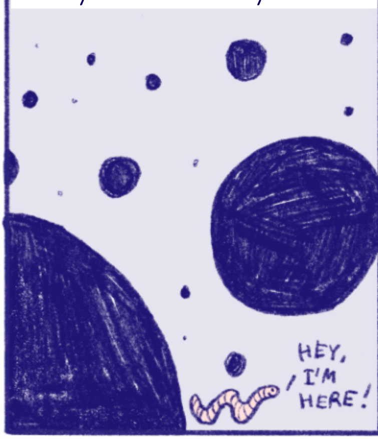


This is why they need G-waves like me! Trust me, we will help with that!

G-wave detectors are not able to see light. But, on August 17, 2017, I happened to come by, they heard me and sent a warning to the astronomers.



The thing is, to find out from which galaxy a G-wave is coming is like looking for a tiny worm in a haystack...

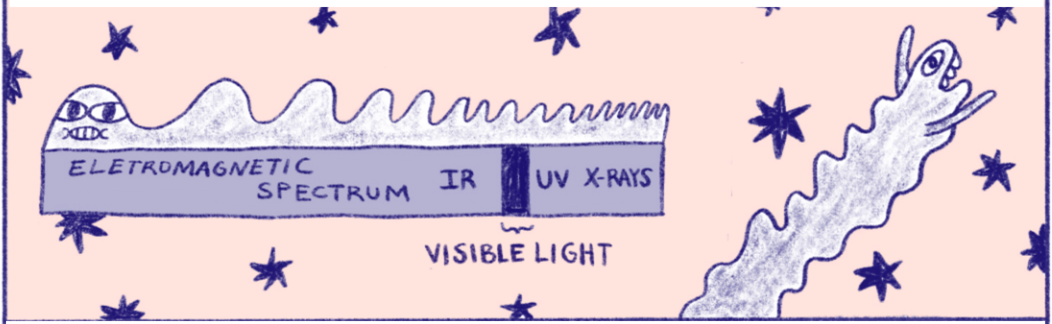


With the warning, astronomers started racing against time, because the light from the neutron star collision disappears within a few days.

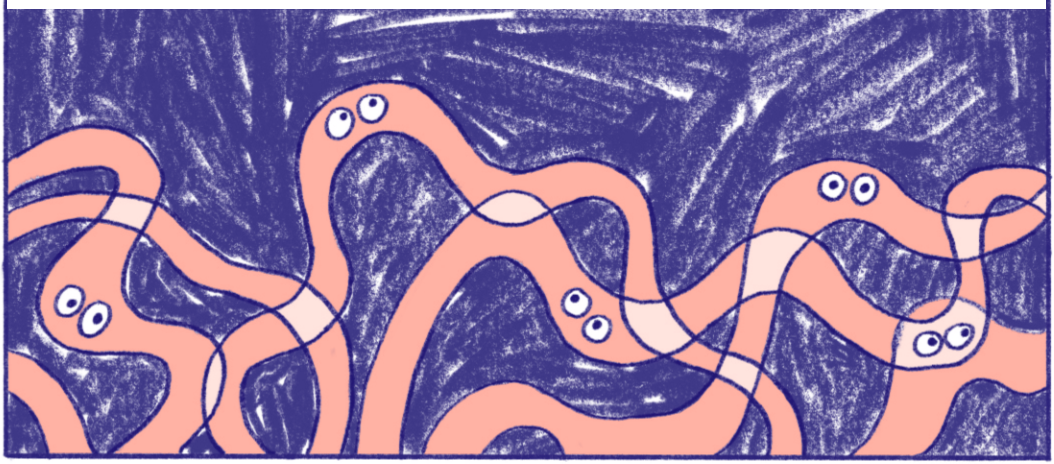
Some astronomers used telescopes to search in specific galaxies, while others searched in a certain region of the sky.

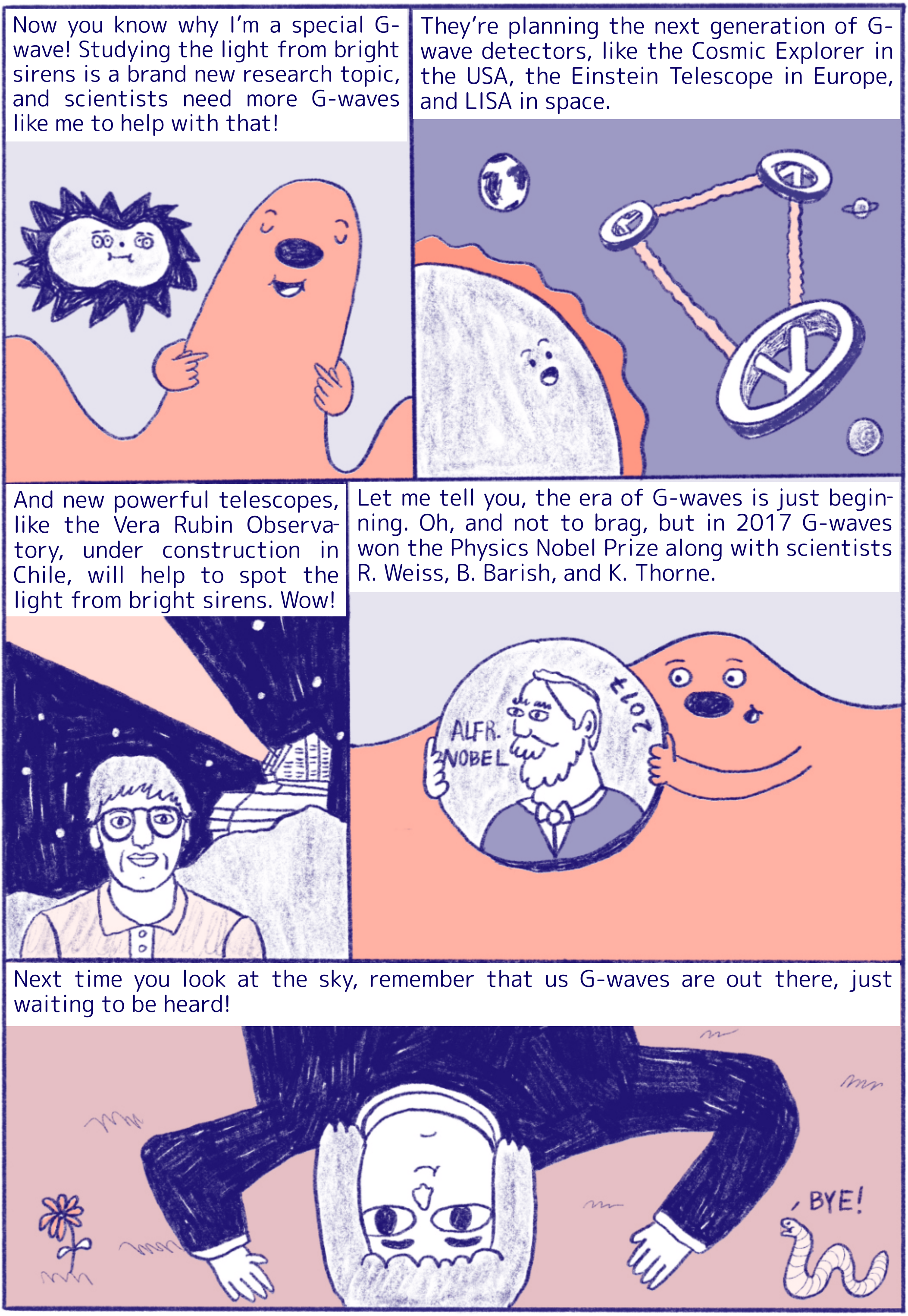
In less than 11 hours since the warning, the Swope Telescope team was the first to spot the light from my birthplace—the first bright siren light ever detected!

And it was a special kind of light, the so-called *kilonova*: a fast-fading blue glow from iron atoms, blasted out when the neutron stars collided. So far, this has been the only time astronomers spotted the bright siren light... They're rare and hard to catch!



Nowadays, scientists detect G-waves weekly, but they usually come from black hole mergers (dark sirens), so there is no light to observe and offer clues about their home galaxies.




Now you know why I'm a special G-wave! Studying the light from bright sirens is a brand new research topic, and scientists need more G-waves like me to help with that!
They're planning the next generation of G-wave detectors, like the Cosmic Explorer in the USA, the Einstein Telescope in Europe, and LISA in space.
And new powerful telescopes, like the Vera Rubin Observatory, under construction in Chile, will help to spot the light from bright sirens. Wow!
Let me tell you, the era of G-waves is just beginning. Oh, and not to brag, but in 2017 G-waves won the Physics Nobel Prize along with scientists R. Weiss, B. Barish, and K. Thorne.
ALFR. NOBEL
2017
Next time you look at the sky, remember that us G-waves are out there, just waiting to be heard!
BYE!

COSMOZINE

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