Everything You Should Know About Sound

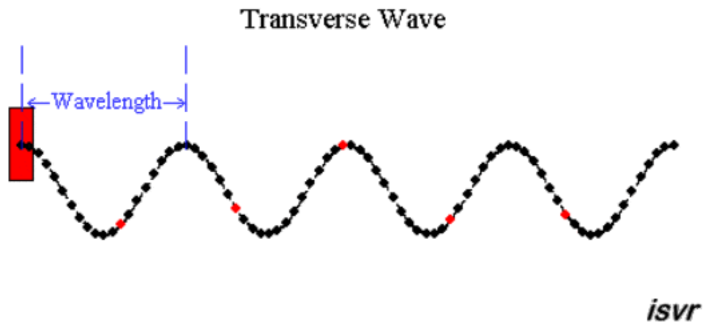
March 9, 2016 By Tim Urban

This post is part of Mini Week, where I'm posting a new mini post but not actually mini as it turns out every weekday this week.

I've always been a little confused about sound. So for "Tuesday's" "mini" post, I decided to do ɿing about that.

ɿk of sound as something we *hear*—something that makes *noise*. But in pure physics terms, is just a vibration going through matter.

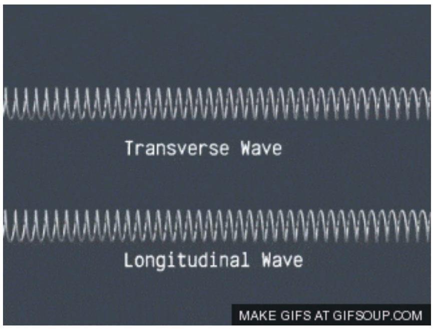
ɿy a vibration "goes through" matter is in the form of a sound wave. When you think of sound you probably think of something like this: [1]



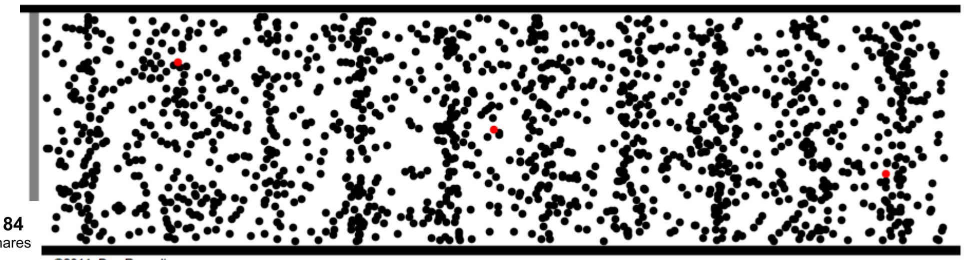
But that's not how sound waves work. A wave like that is called a transverse wave, where each individual particle moves up and down to create a snake situation.

A sound wave is more like an earthworm situation: [2]

Like an earthworm, sound moves by compressing and decompressing. This is called a longitudinal wave. A slinky can do both kinds of waves: [1] [3]



Sound starts with a vibration of some kind creating a longitudinal wave through matter. Check this out: [4]



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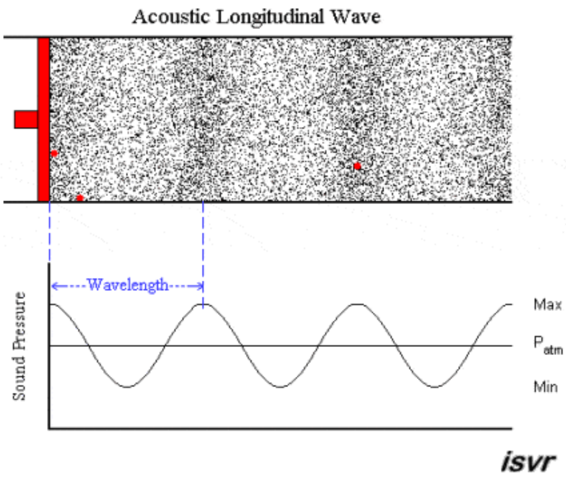
what sound looks like—except picture an expanding ripple of *spheres* doing that. In this :ion, the sound wave is being generated by that vibrating grey bar on the left. The bar might be ɔcal chords, a guitar string, or a waterfall continually pounding down into the river below. By ȝ at the red dots, you can see that even though the wave moves in one direction, each individual ɘ only moves back and forth, mimicking the vibration of the gray bar.

...ead of a curvy snake wave, sound is a *pressure* wave, which causes each piece of the air to be at either higher-than-normal pressure or lower-than-normal pressure. So when you see a snake-like illustration of a sound wave, it's referring to the measure of pressure, *not* the literal path of movement of the particles: [5]



Sound waves can go through air, which is how we normally experience it. But it can also go through liquid [2] or solid matter—much of the jolting that happens during an earthquake is the result of a huge sound wave whizzing through the earth (in that case, the movement of the fault is serving as the gray and red bars in the animations above).

How about the speed of sound? Well it depends on how quickly the pressure wave can move in a given medium. A medium that's more fluid, like air, is highly compressible, so it takes longer for the wave to move, while water is far less compressible, so there's less "give" to slow the wave down. It's like two people holding an outstretched slinky between them—if one pushes their end toward the other person, the wave will take a little time to travel down the slinky before the other person feels it. But if the two people are holding a broomstick, when one pushes, the other feels it immediately, because the broomstick is much less compressible. [6]

So it makes sense that the speed of sound in air (768 mph / 1,234 kmph under normal conditions) is about four times slower than the speed of sound in water, which itself is about four times slower than the speed of sound through a solid like iron.

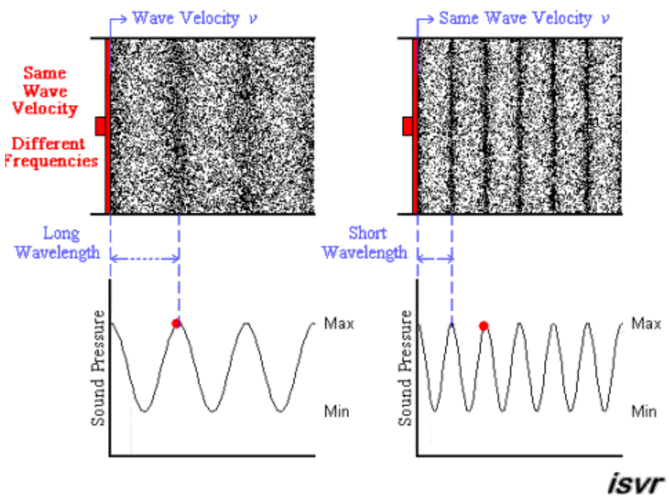
Back to us and *hearing*. Ears are an evolutionary innovation that allows us to register sound waves in the air around us and process them as information—without ears, most sound waves would be imperceptible to a human with only the loudest sounds registering as a felt vibration on our skin. Ears give us a magical ability to sense even slight sound waves in a way so nuanced, it can usually tell us exactly where the sound is coming from and what the meaning of it is. And it enables us to talk. The most important kind of human communication happens when our brains send information to other brains through complex patterns of *air pressure waves*. Have you ever stopped and thought about how incredible that is?

I was about to move on, but sorry, I can't get over this. The next time you're talking to someone, I want you to stop and think about what's happening. Your brain has a thought. It translates that thought into a pattern of pressure waves. Then your lungs send air out of your body, but as you do that, you vibrate your vocal chords in *just* the right way and you move your mouth and tongue into *just* the right shapes that by the time the air leaves you, it's embedded with a pattern of high- and low-pressure areas. The code in that air then spreads out to all the air in the vicinity, a little bit of which ends up in your friend's ear, where it passes by their eardrum. When it does, it vibrates their eardrum in such a way as to pass on not only the code, but exactly where in the room it came from and the particular tone of voice it came with. The eardrum's vibrations are transmitted through three tiny bones and into a ıc of fluid, which then transmits the information into electrical impulses and sends them up the ry nerve and into the brain, where the information is decoded. And all of that happens in an of a second, without any effort from either of you. Talking is a *miracle*.

y—

r can discern many qualities of a sound it hears, but two of the most fundamental are pitch and ɛss.

; all about wavelength—i.e. how far apart the pressure waves are: [7]



The shorter the wavelength, the higher the pitch. Humans can hear frequencies as low as 20 Hz (which is a 56 ft /17 m long wave) and as high as 20,000 Hz (.7 in / 1.7 cm). As you age, you lose your ability to hear the highest pitches, so most of you probably hear nothing when you listen to the frequencies approaching 20,000 Hz (your dog will disagree). But you'll have an easier time hearing the lowest part of the range. [8] The reason you can *feel* low sounds, like low bass notes in music, is that the wavelength is so long that it actually takes 1/20th of a second for a full wave to pass your body (hence 20 Hz). [3] [4]

Loudness

The loudness [5] of a sound we hear is determined by the *amplitude* of the pressure waves. In the animation above, the high and low-pitched sounds depicted have the same loudness, because the pressure curves at the bottom of the animation are the same size *vertically*. Louder sounds have a larger oscillation between the low and high pressure sections of the wave—i.e. loud sounds have higher high-pressure and lower low-pressure parts than quiet sounds.

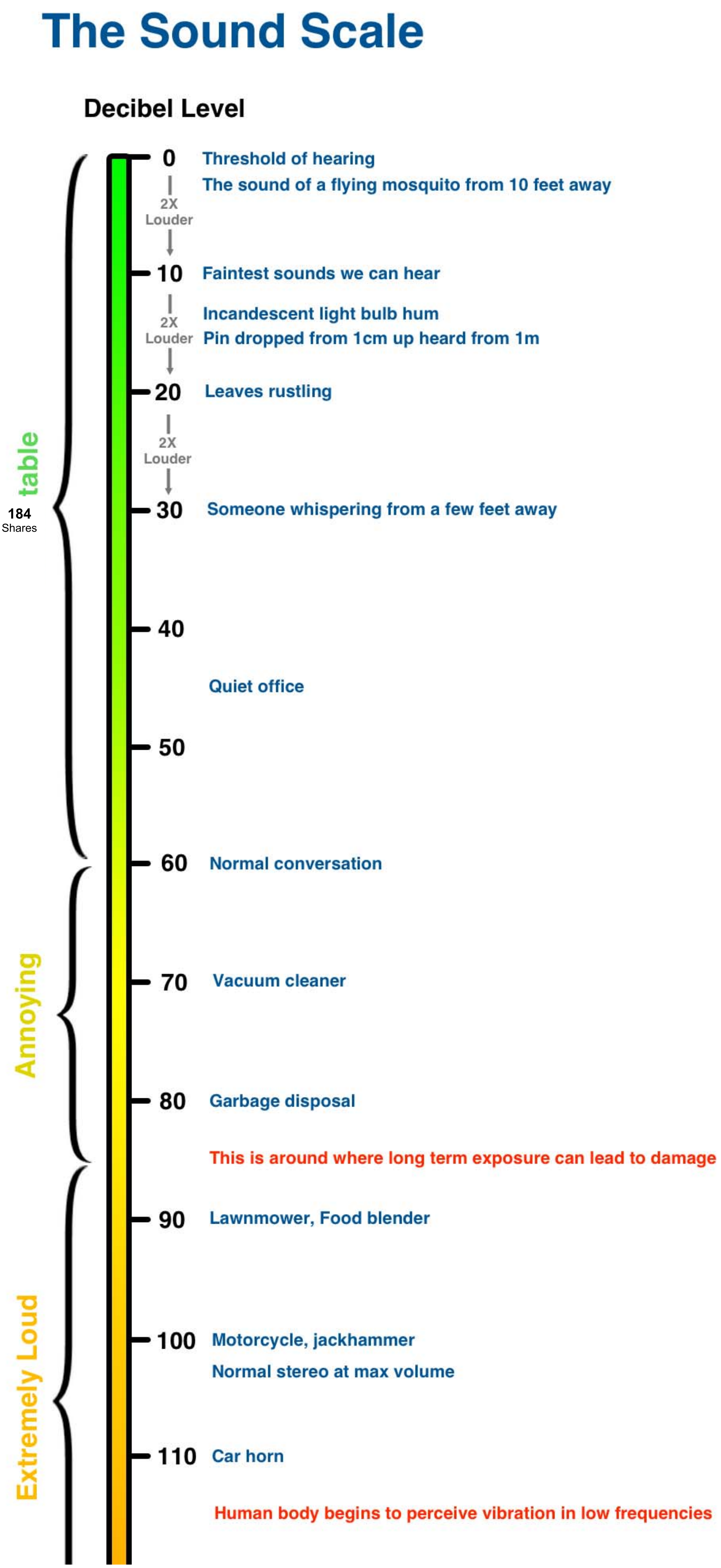
For sounds through the air on Earth's surface, the average of the high-pressure and low-pressure parts of the wave is our normal atmospheric pressure—what we call 1 "atmosphere" of pressure. So a sound wave might have a high pressure component of 1.0001 atmospheres and a low pressure component of .9999 atmospheres, and a louder sound might be 1.01/.99 instead—but in both cases, the average of the two is 1 atmosphere.

We often measure loudness using a unit called the decibel (named after Alexander Graham Bell). If you want to be confused, read the Wikipedia page on decibels. It's a super icky unit. And rather than bore us both by explaining it, let's just talk about how we use decibels to measure sound.

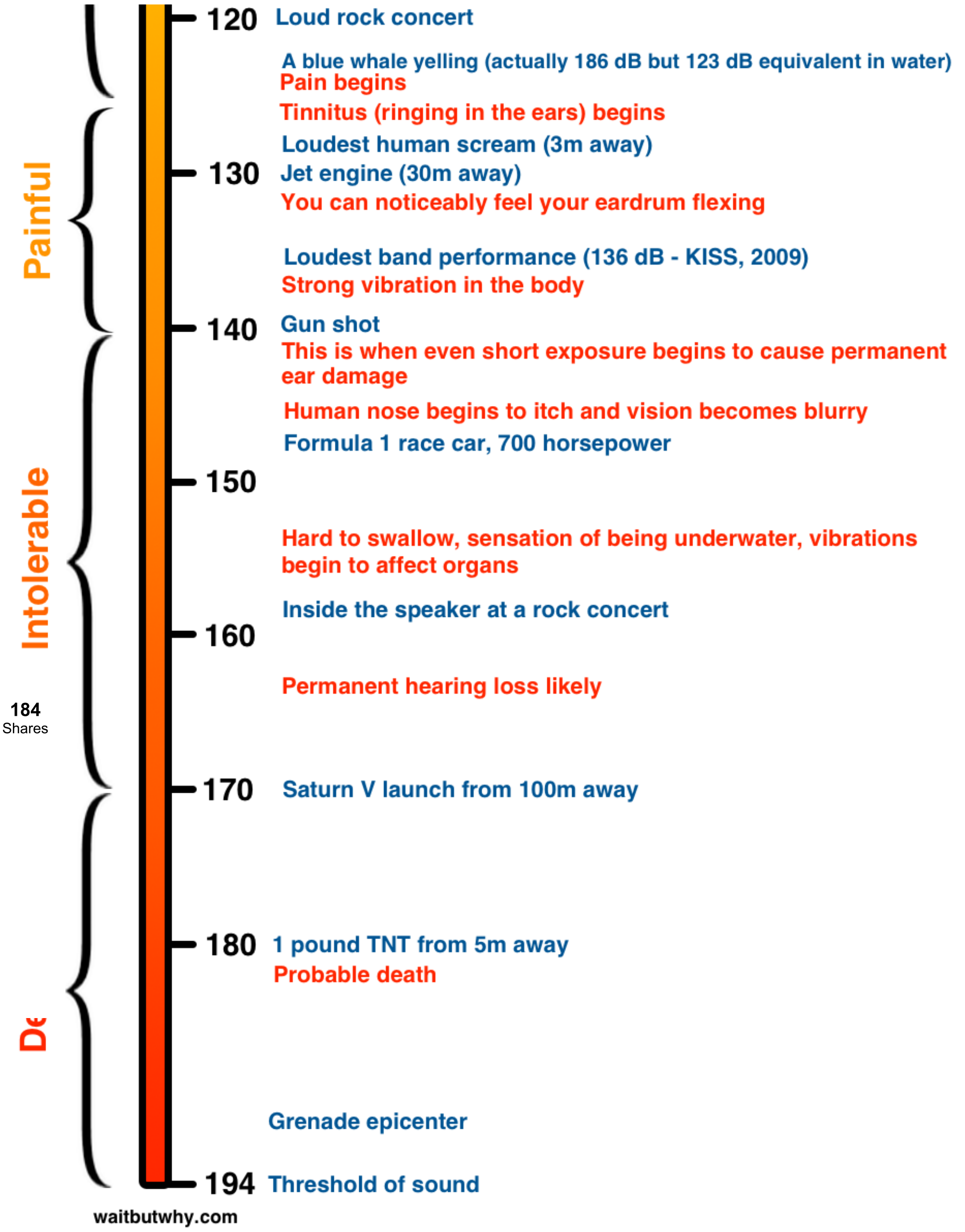
The scale of loudness has a very tiny minimum. The faintest sounds are far softer than any human could hear—even softer than any of our finest scientific instruments could detect. But depending on where you are, sound has a hard maximum. The reason is that sound isn't a thing in itself—it's a pressure wave moving through a medium. And since, as we talked about, the average of the high and low pressure points of a sound wave has to be the normal pressure of the medium, loudness is limited by the fact that eventually, the low pressure point hits zero-pressure—a vacuum. Since the low pressure can't go any lower, that point determines the max amplitude of a sound wave, and the loudest a sound can be, in any given place.

The convenient thing about decibels (dB) is that the absolute faintest sound detectable to the human ear is, by definition, 0 dB—we call that "the threshold of hearing." Scientists do their best to study sounds far down into the negative decibel scale and there are man-made rooms on Earth that register as low as -9.4 dB—where it's so quiet you can hear the blood pumping through your own brain—but we ly hear sounds in the dB positives. The loudest a sustained sound can possibly be on Earth's e is 194 dB—which is when the amplitude of the sound wave is so intense that the low pressure a perfect vacuum (the wave alternates between double the normal atmospheric pressure and no ll—not something you want to be present for). Let's take a look at the full scale, starting with the quiet.

ing to keep in mind is that with decibels, each increase of 10 dB *doubles* the loudness. So 20 dB is s loud as 10 dB, 30 dB is four times as loud as 10 dB, and 80 dB is 128 times louder than 10 dB. [6]


The Sound Scale
Decibel Level
0 Threshold of hearing
The sound of a flying mosquito from 10 feet away
2X Louder
10 Faintest sounds we can hear
Incandescent light bulb hum
Pin dropped from 1cm up heard from 1m
2X Louder
20 Leaves rustling
2X Louder
30 Someone whispering from a few feet away
40
Quiet office
50
60 Normal conversation
70 Vacuum cleaner
80 Garbage disposal
This is around where long term exposure can lead to damage
90 Lawnmower, Food blender
100 Motorcycle, jackhammer
Normal stereo at max volume
110 Car horn
Human body begins to perceive vibration in low frequencies
table
Annoying
Extremely Loud


THE WBW STORE



The scale stops at 194 because there's no such thing as a louder sound on Earth's surface. But we can go beyond here in two ways:

1) Shock Waves

When enough energy is released to pass the 194 dB mark, it's too much to create a sustained pressure *wave* because we've bottomed out on low pressure—but things still *happen*. Very, very intense things.

At 194 dB, there's a maxed out wave alternating between double the normal pressure and a total vacuum—but once we get to 195 dB, the energy stops moving *through* the air and starts *pushing* the air outward with an expanding vacuum. The more dBs above 194 there are, the farther reaching and higher-impact that vacuum bubble will be. It expands outward as a rapidly-growing half-sphere: [10]

On the edge of the bubble is a barrier of super-compressed gas, and when this barrier sweeps over the land, it usually flattens whatever's in its path: [11]

As the hemisphere expands, it loses energy and eventually dissipates. But if you found yourself in the path of a shock wave before that happened, you'd have a bad time. First, the impact of the super-compressed barrier would be like hitting a brick wall (in the same way and for the same reason falling on water from a bridge is like falling on concrete). Second, compressed air is *hot*. Third, it wouldn't just hit all parts of your body, it would go *through* your body, and if it were powerful enough it could turn ' ones to powder and your organs to soup.

re some famous 194dB+ events:

ı V launch: The Saturn V was a beast, and the sound waves from its launches were so intense ey could light grass on fire a mile away. Even at three miles away, an observer would experience itting 135 dB sound. [12] Rocket launches create such a powerful sound, that space agencies flood ınchpad with water as the rocket launches to absorb the sound so the force of the pressure wave t damage the rocket.

roshima and Nagasaki bombs: According to sources I read, these clocked in at well over 200 e shock wave was so charged that it traveled 7 mi / 11 km in 30 seconds.

The 1883 Krakatoa volcano eruption: [13] I'm overwhelmed by the amount of things I need to tell you about the Krakatoa. Let's do bullets.

- Krakatoa is an island in Indonesia, and the eruption happened on August 27, 1883.
- The eruption completely annihilated the island, sending an enormous amount of debris 17 miles (27 km) high into the sky at half a mile per second. It also caused one of the most deadly and far-reaching tsunamis in history. In total, the eruption killed 36,000 people.
- But the most amazing thing about the eruption was its sound. It made arguably the loudest sound on Earth in modern history.
- It was so loud that the shock wave extended far enough to rupture the eardrums of sailors 40 miles away.
- 100 miles away, the sound was still 172 dB, enough to permanently destroy someone's ears or even kill them. Wherever you are, think of a place that's about 100 miles (161 km) away. Now imagine something happening there that causes a sound so loud where *you* are that if you were screaming at the top of your lungs directly into someone's ear when the sound hit, they wouldn't be able to hear that you were doing it. For comparison, the Saturn V launch sound was at 170 dB 100 *meters* away. Krakatoa was higher than that 100 *miles* away.
- The sound cracked a foot-thick concrete wall 300 miles (483 km) away.
- The sound was heard all the way in Australia (where it sounded like a distant canon ball being fired) and even as far away as Rodrigues Island, 3,000 miles away. *3,000 miles away*. I'm currently in New York. *Imagine if something happened in California or in Europe that I could hear in New York.* I can't even.
- After the sound eventually got far enough away that humans couldn't hear it anymore, barometers all over the world were going nuts for the next few days, as the sound waves circled the Earth *3.5 times*.
- Finally, you know the famous painting The Scream? Well you know how the sky's all red for some reason? The sky is red because the painter, Edvard Munch, was inspired to paint it after seeing the Krakatoa-caused red skies all over the Western Hemisphere in the year after the eruption.

It was a big eruption.

2) Other Mediums

There *can* be louder sound than 194 dB—just not on the Earth's surface. There can be louder sounds in the ocean, in the land, or on other planets. The gas giants in our Solar System, for example, have denser atmospheres than Earth's, which allow for higher pressure wave amplitudes, and with incredibly fast winds and powerful storms, there's plenty of opportunity there to make loud things.

What *isn't* loud is almost everything else in space. You've probably heard the term, "Sound doesn't travel in a vacuum," but it makes sense now, right? Sound is pressure waves through matter. If there's no matter, there's no sound. There can be immense *heat*, and *radiation*, and *force*, but to a nearby observing human, it's all dead silent.

If, hypothetically, there *were* air filling the universe, then suddenly things would get *very* loud. Forget the terrifying concept of the sound of a supernova—just the dumb sun sitting there hanging out would ring in at an astounding 290 dB. According to one solar physicist, we'd hear that on *Earth* as a 100 dB sound—*the volume of a motorcycle*—all the time, every day, everywhere. Be happy that sound doesn't travel in a vacuum.

One last thought—

Researching for this post and learning about what sound is gave me a new perspective on the tree falling in the forest with nobody there to hear it question. I now think that no, it doesn't make a sound. It makes an air pressure wave and that's it. The concept of sound is by definition a biological being's perception of the pressure wave—and if there are no ears around to perceive the pressure wave, there's no sound. It's a little like asking, "If humans go extinct, and somewhere in the post-apocalyptic , there's a photo of a beautiful woman lying there—is she still beautiful?" I kind of don't think Because the only thing that's beautiful about her is that humans found her beautiful, and ıt humans, she's no more beautiful than the female beetle a few feet away, rummaging around ɔble. Right?

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Sources

The awesome GIFS: Dan Russell and ISVR
CDC: Noise and Hearing Loss Prevention
US Department of Labor: Occupational Noise Exposure
Nautil.us: The Sound So Loud That It Circled the Earth Four Times
UNSW: What is a Decibel?
Decibelcar.com: Decibel Equivalent Table
Make it Louder: Ultimate Sound Pressure Level Decibel Table
NASA: Sound Suppression Test Unleashes a Flood
Idiom Zero: How Loud is the Sun?
Gibson.com: It Might Get Loud: The 10 Loudest Rock Bands of All Time
GC Audio: Decibel (Loudness) Comparison Chart
Mathpages.com: The Speed of Sound
Turn it to the Left: Noise Levels
Extreme Tech: Can a Loud Enough Sound Kill You?
Abelard.com: Loud Music and Hearing Damage
Soundproof Cow: Loudest Sound Ever Heard
Chalmers: Quantum microphone captures extremely weak sound
born.gov.au: The eruption of Krakatoa, August 27, 1883

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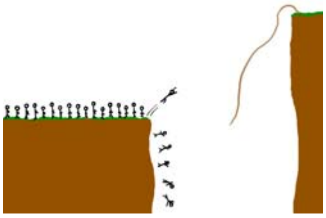

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Gusssss • 5 days ago

"The most important kind of human communication happens when our brains send information to other brains through complex patterns of air pressure waves. Have you ever stopped and thought about how incredible that is?"

Yes I have! And since I'm a physicist/cosmologist who doesn't think we are supernatural beings who have free will to control matter in this way, I have to try to come to terms with the fact that this process has arisen spontaneously through interactions between subatomic particles since the big bang.

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Tara • 3 months ago

OMG that is amazing! The way you explained it was just brilliant and it really helped me understand what I'm learning in science to a higher degree. Very interesting.

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songlin tu • 4 months ago

very interesting post. by the way, can i translate this to

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