Why Gravity is Not a Force: A No-Math-Needed Explanation

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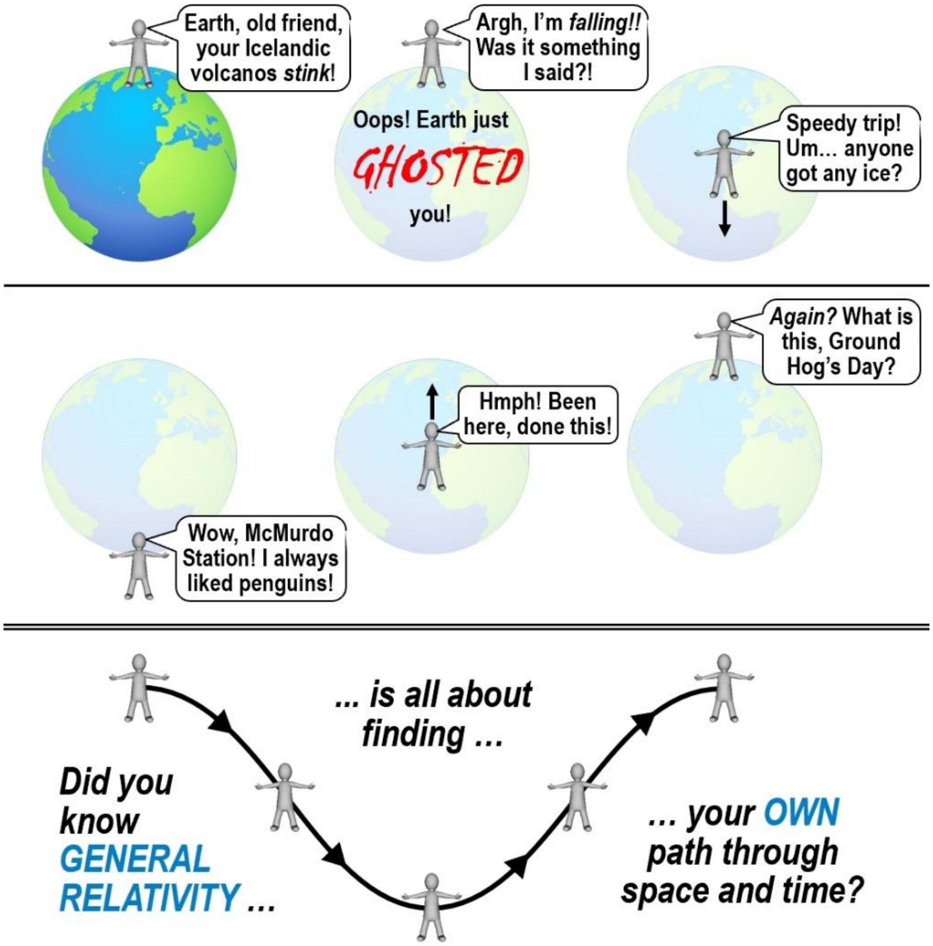

Figure 1. *Gravity is all about paths through space and time. Earth "ghosting" you reveals the truth.*

Ghost Orbits

Physicists are fond of saying that gravity is not a force like the electric force. That is a baffling statement since, for most of us, gravity *defines* a force: A push (or pull) that tries hard to move you in some direction. Given that, what does it even *mean* to say something that pulls you inexorably downward is not a force?

The best way to understand a problem in science is to eliminate details that confuse the situation. In the case of gravity, one of those details is Earth itself — not the *gravity* of Earth but the way its rocks and materials behave. Let's eliminate those unnecessary details and see if we can understand Earth's gravity from a new perspective. Fig. 1 shows the thought experiment.

Imagine you are in Iceland observing the latest volcanic action when the entire Earth suddenly decides to ghost you. Earth's *gravity* remains, but its rocks, water, and air all decide to stop interfering with gravity to slow or stop you from falling. What happens?

The first and instantaneous change is that you go into *freefall*. Gravity seems to disappear, and you no longer have a well-defined sense of up and down. Astronauts see this same effect in orbits and parabolic practice flights.

The other immediate effect is that you begin accelerating. Physics professors often assign a famous problem called the gravity tunnel students, and the answer to this problem is the same one needed for the ghost Earth problem. They ask students how long it takes to fall through an empty tunnel from one side of the Earth to the other. The answer most often given is that the trip takes 42 minutes — and yes, "the answer is 42" applies here — but a more careful calculation that takes the non-uniform nature of Earth into account [1] gives about 38 minutes. Only nineteen minutes later, you are zipping through the center of Earth's core at eight kilometers per second. After that, you begin decelerating. Popping out and briefly coming to a standstill somewhere near McMurdo Station in Antarctica, you then start the inverse fall, traveling once again through the core and back to near your starting point.

To say this is an oversimplification is a bit of an understatement since there are factors, such as the rotation of the Earth and orbital motion, that I've not included. But that's not the main point here. The important question is this: What, exactly, happens to you when *only* gravity affects you and not the other features of rock, water, and air?

The answer is twofold. First, you acquire a much different personal path through space. Instead of cycling once per day around the Earth, you acquire a motion like an enormous sine wave with a frequency of one cycle every 76 minutes. If you want to think of that as a sound, it's about 219 micro-Hertz, which is not a unit you encounter often.

Second, you *stay in freefall* for as long as the Earth remains a gravity-only ghost. One way to understand why this happens is that you are in a special orbit that only goes up and down instead of round and round. Such "ghost orbits" are possible only if the Earth lets you through unimpeded, but it's an orbit nonetheless.

(For any chemists, this up-and-down orbit has another name: an *s* orbital. While *s* orbitals are quantum, they work the same way and are classically equivalent to the electrons diving straight through the nuclei of the atoms. Such electrons don't collide with nuclei because particle physics has a real form of ghosting in which the electrons and protons cannot "see" each other until the electrons reach extremely high energies.)

Taking a Closer Look at Freefall

Since it's the most persistent element of all orbits, including ghost orbits, it's time to look closer at what freefall is from a physics perspective. Fig. 2 shows what happens if you carry a portable physics lab on your ghost orbit.

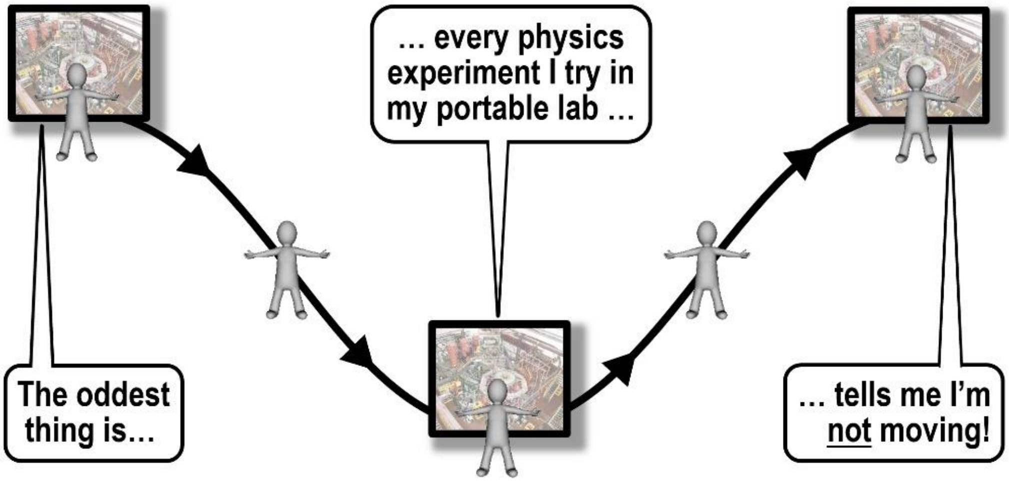

Figure 2. *When is motion not motion? When you stick to your unique path through space and time.*

The interesting thing about freefall is that, to the degree that your orbit is "perfect" and decently free of more detailed effects such as tides — those resulting from slightly different locations having slightly different orbits — what you see with your instruments is quite odd: They tell you *are not moving at all*. This apparent lack of motion is true even when applying your fanciest instruments, such as advanced optical devices that check how light goes back and forth in complicated geometries within your instrument set.

Uh… what? All you have to do is look around you to see that you are moving rapidly relative to Earth, the Sun, and many other objects in the Solar System. In fact, as best you can tell by looking around, you are the *only* object and lab moving quickly up and down at 219 micro-Hertz. How can it be that the instruments you carry with you are not telling you *any* of that? It seems a bit silly.

The critical word in all of this is *relative*. As long as *you* make the measurements using only *your* instruments, they tell you that every feature of quantum electrodynamics, particle physics, and light is standard. When you take measurements relative to other objects in the universe, you come up with conflicts. *Those* measurements tell you that if you are truly at rest, then the rest of the universe must be bobbing up and down at 219 micro-Hertz, which makes no sense. You know that *you* are accelerating up and down due to Earth's gravity, not the rest of the universe.

Relativity: The *Special* and *General* Theories

There is a reason why both of Einstein's most famous theories have the word *relative* in them. They both address the same issue: As long as you remain in freefall, it doesn't matter how complicated your path through space and time becomes. *You* always perceive *your* physics as invariant and unable to discern the shape of your freefall path. You can only detect these paths by making measurements *relative* to other objects in the universe. It is not part of your internal, portable-lab definition of classical, quantum, and particle physics.

If your relative path is close to a straight line, it's called *special relativity*. If it has lots of loops and curves in it, it's called *general relativity*. That's the only difference between the two, and this emphasizes why the *special* theory is so much narrower than the *general* theory. In the cosmos, long, curve-free freefall paths are exceedingly rare in most of space. The *special* theory thus works best for small-scale lab situations in which the distances are too small for curved paths to come into play. The special theory is never anything more than an approximation.

Gravity as Argument

You may have noticed that I avoid the word gravity when discussing these *relative* curved paths. That's because I'm trying to flip your perspective a bit: Your personal physics and curved relative paths are the more fundamental components of the universe. The "force" of gravity emerges from a very different source: the *collision* of two or more such relative paths. In other words, gravity is an *argument* (Fig. 3).

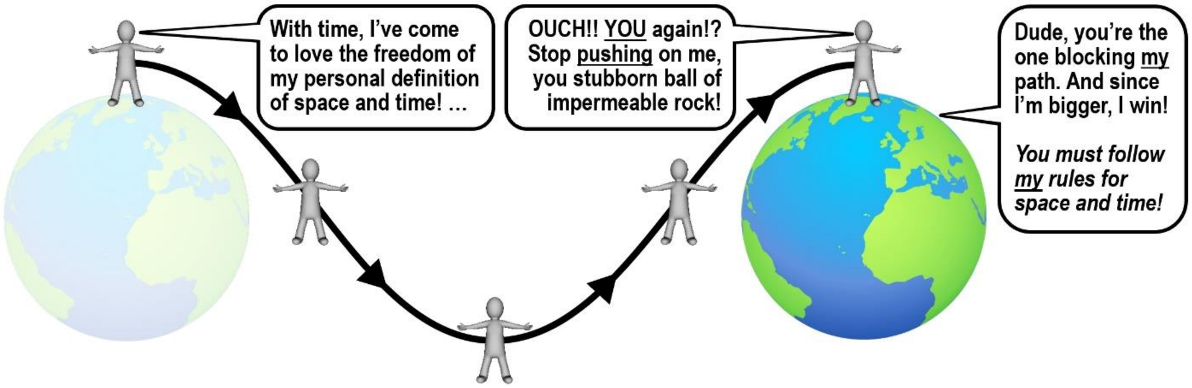

Figure 3. *When personal space and time paths collide, guess who wins?*

Figure 3 points out what happens if the *material* features of Earth decide to stop ghosting your 219 micro-Hertz *relative* path by getting in the way again. Luckily, Earth decides to do this when you reach the Icelandic peak of your ghost orbit, keeping you from getting either splatted by velocity or embedded in rock. What happens instead is an *argument*. You've gotten accustomed to being the "only" stationary object in the universe, at least as far as your instruments can tell, and you no longer like the material parts of Earth getting in your way.

Meanwhile, Earth feels like you do: It wants to continue *defining* space, time, and physics. However, the Earth is much more massive than you are, and ends up winning this argument. You keep trying to go your way, creating your definition of space, time, and physics… but *can't* fully implement them because massive Earth has swept you up in its definition.

You end up with a one-sided compromise: You *both* end up pushing against each other (Fig. 4) as you attempt to follow your desired freefall paths, but only *Earth* has enough mass to sweep you along with it. Only the Earth ends up with a good approximation of its freefall path, better known as "the Earth's orbit around the Sun."

Figure 4. *"I know we're both feeling a lot of pressure, but can we just agree to disagree?"*

So there it is: Gravity is not a force but an *argument* between two bodies that each want to maintain their unique definitions of space, time, quantum mechanics, and particle physics. Each one *pushes* to enforce its definition.

I've left out a lot, of course. If ghost orbits — freefall orbits — are the deeper parts of physics, how do these strange, curvy *relative* paths emerge? That's for another time, but Archibald Wheeler had a knack for capturing the essence of mathematically complicated ideas in short, punchy statements [2]. The relevant quote in this case is:

> *"Spacetime tells matter how to move; matter tells spacetime how to curve."*

The full richness of *general* relativity — and by far the most complicated math — comes from defining how matter tells spacetime to curve. That broader topic is for some other time.

References

[1] A. R. Klotz, *The Gravity Tunnel in a Non-Uniform Earth*, American Journal of Physics **83** (3), 231–237 (2015). https://arxiv.org/abs/1308.1342

[2] J. A. Wheeler and K. W. Ford, *Geons, Black Holes and Quantum Foam: A Life in Physics* [Page 235]. W.W. Norton & Company, 2000. https://books.google.com/books/content?id=zGFkK2tTXPsC&pg=PA235&img=1&zoom=3&sig=ACfU3U00wtxrmg76gzNSYxmny1wwGes7oA.