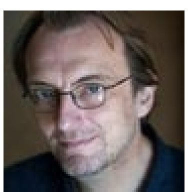
Outlook Perspective

Everything you thought you knew about gravity is wrong. What you think you “know” is a series of illusions

Astronauts Shane Kimbrough and Sandra Magnus, both STS-126 mission specialists, float with fresh fruit on the middeck of Space Shuttle Endeavour on November 16, 2008. (NASA/Johnson Space Center/NASA/Johnson Space Center)



By Richard Panek

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We don’t know what gravity is.

Say that to the average person, and the answer you’ll probably get is some version of: “What are you talking about? Gravity is the force of attraction that makes things fall straight down.” But say it to a physicist, and the answer you’ll get is, “That’s right.”

I know, because those are the two answers I've been getting for the past few years, ever since I figured out that nobody knows what gravity is, and that just about nobody knows that nobody knows what gravity is. The exception is physicists: They know that nobody knows what gravity is, because they know that *they* don't know what gravity is.

The assumption that they do — that we all do — is understandable. Unless you think hard about gravity, your brain does what it evolved to do: It associates gravity with your relationship to the ground beneath your feet. You don't have to think about gravity because you know it in your bones. But if you do think about it, you can begin to realize that what you "know" is, in fact, a series of illusions. These misunderstandings make the universe more navigable — physically and psychologically — and also leave it less mysterious.

Consider the assumptions underlying that common answer:

"Gravity is the force of attraction that makes things fall straight down."

Well, yes — depending on what we mean by "force." We can say gravitation is one of the four fundamental forces, but it's such an outlier that the word "force" becomes nearly meaningless. The strong nuclear force (which keeps atomic nuclei intact) is about 100 times stronger than the electromagnetic force (which creates the light spectrum), which in turn is up to 10,000 times stronger than the weak nuclear force (which facilitates the subatomic interactions responsible for radioactive decay). Three forces, all within six orders of magnitude of one another. Then comes gravitation. It's about a million billion billion billion times weaker than the weak nuclear.

To put that discrepancy into perspective, you can try this experiment at home. Place a paper clip on a tabletop. There it remains, unmoving, anchored to its spot by its gravitational interaction with the entire planet beneath it. The Earth's mass is 6,583,003,100,000,000,000,000 tons. A paper clip's mass is 4/100 of an ounce. Now take a refrigerator magnet and wand it over the paper clip. Presto! You have counteracted the gravitational "force" of the entire Earth with a wave of your hand.

Even more unnerving to physicists is that gravitation is the only force that doesn't have a quantum solution — a theory that explains the force in terms of subatomic particles. The strong nuclear has quantum chromodynamics, electromagnetism has quantum electrodynamics, the weak nuclear has quantum flavordynamics. Gravitation has quantum bupkisdynamics. (The discovery of the graviton — a hypothetical particle that would mediate with nature on gravity's behalf in the same way that the gluon does for the strong nuclear, the photon does for electromagnetism, and the W and Z bosons do for the weak nuclear — would help. But if it exists, it has escaped detection with a cunning unparalleled in quantum experiments.)

So let's strike "force" from our answer. In that case: "Gravity is the attraction that makes things fall straight down."

Well, yes — depending on what we mean by "attraction." Two bodies of mass don't actually exert some mysterious tugging on each other. Newton himself tried to avoid the word "attraction" for this very reason. All (!) he was trying to do was find the math to describe the motions both down here on Earth and up there among the planets (of which Earth, thanks to Copernicus and Kepler and Galileo, was one). Still, he was as powerless as a paper clip once the idea of attraction at a distance electrified the public.

So: “Gravity is what makes things fall straight down.”

Well, yes — depending on what we mean by “straight down.” The path seems straight only because you’re standing still relative to the Earth. As Galileo realized, if you drop a rock from the mast of a ship traveling on a river, its trajectory will appear to be an angle to an observer on the shore. Similarly, to someone outside the Earth who is observing a rock falling on our spinning planet, the path would appear to be on an angle. But the Earth is also orbiting the Sun, so that angle would actually be swooping, creating the appearance of a curve. And because the Sun is orbiting the center of the galaxy, that curve would be a very long curve. And the galaxy is moving toward other galaxies, and the universe is expanding, and the expansion is accelerating: How long and curlicued the rock’s trajectory appears depends wholly on where you are in relation to it.

So: “Gravity is what makes things fall.”

Well, yes — depending on what we mean by “fall.” We can just as easily argue — as Einstein did, expanding on Galileo’s ship/shore relativism — that the rock isn’t falling toward the Earth but that the Earth is rising toward the rock.

So: “Gravity is.”

Well, yes — depending on what we mean by “is.” We know what gravity does, in the sense that we can mathematically measure and predict its effects. We might anticipate what happens when two black holes collide or when we let go of a rock. But we don’t know *how* it does what it does. We know what its effects are, and we can give the name “gravity” to the cause of those effects, but we don’t know the cause of that cause.

Not that cosmologists particularly care. In science, knowing what you don’t know is a good start. In this case, it has led scientists to believe that finding a quantum solution to gravity is a key — perhaps *the* key — to understanding the universe on the most fundamental level. Until then, they will work with what they do know, no matter what every bone in their bodies tells them:

Gravity is not the force of attraction that makes things fall straight down.