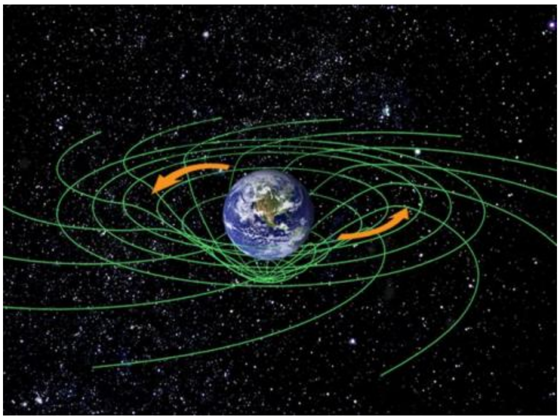
Einstein's Theory of General Relativity - Explained



A NASA space vehicle, known as "Gravity Probe B," has measured the curved space-time around the Earth. The principal investigator of the probe's mission was Stanford University's Francis Everitt, who said: "The space-time around Earth appears to be distorted just as general relativity predicts." This artists' conception—by copyright holders James Overduin, Pancho Eekels and Bob Kahn—depicts the probe's findings. Online via NASA; fair use for educational purposes.

Contrary to what every single person alive at the time believed, in 1915 Albert Einstein figured-out a new theory of space and time. His theory led to a new way of simplifying physics.

Instead of understanding “space” and “time” as separate concepts, or separate physical constructs, Einstein wondered: Why not think of “space” and “time” as one—and call it “spacetime?”

Were we to think of “space” and “time” as a single combined reality, it would have to be a 4-dimensional object because space is 3-dimensional—up/down, left/right, forward/backward—and time is 1-dimensional. It would also have to be a “continuum” because—as far as scientists have been able to determine—there aren’t any missing points in space or missing instants in time.

Dr. Sten Odenwald, a space scientist writing on behalf of NASA, tells us how physicists have responded to this Space-Time idea:

> *...physicists now routinely consider our world to be embedded in this 4-dimensional Space-Time continuum, and all events, places, moments in history, actions and so on are described in terms of their location in Space-Time.*

How does gravity fit into Einstein’s General Theory of Relativity? It is part and parcel of it.

For one thing, Einstein went much farther than Isaac Newton (who pondered the mysterious force of gravity—then unnamed as a force—when he reportedly saw an apple fall from a tree at his mother’s home). As Tom Siegfried observes in a *Science News* article:

> *Newton’s law of gravity had united the earthly physics of falling apples with the cosmic dances of planets and stars. But he couldn’t explain how, and he famously refused to try. It took an Einstein to figure out gravity’s true modus operandi. Gravity, Einstein showed, did not just make what goes up always come down. Gravity made the universe go ’round.* (See "Einstein's Genius Changed Science's Perception of Gravity," *Science News*, Vol. 188, No. 8, October 17, 2015, p. 16.)

For another thing, Einstein said that mass—the “m” in his famous equation E=mc2—causes spacetime to curve.

Curve spacetime?! How does *that* work?

Well ... the natural motion of things is to follow the simplest path through spacetime. However ... since objects-with-mass curve spacetime, matter will move toward the most massive object. Gravity plays a major role in this:

> *Gravity, said Einstein, actually moved matter along the curving pathways embodied in spacetime—paths imprinted by mass and energy themselves.* (Siegfried, at page 16.)

Decades after Einstein’s revolutionary theory, John Archibald Wheeler—the brilliant physicist (and teacher of Richard Feynman) who coined the terms “worm hole” and “black hole”—elegantly described how mass, gravity and spacetime work together:

> *Spacetime grips mass, telling it how to move; and*
> *Mass grips spacetime, telling it how to curve.* (See *Spacetime Physics*, at page 275.)

Standing on the ground, we experience movement-toward-the-most-massive-object—in our case, the Earth—as gravity. According to Einstein ... it’s warped space and time which keeps our feet on the ground.

Warped space? That sounds a bit like science-fiction, doesn’t it?

Not really ... if you think about the curving of spacetime.

Have a look at this animation from the Science & Technology Facilities Council (which is narrated by David Tennant of “Dr. Who” fame). Move the video forward to 1:21 to see an explanation of warped space. (Keep in mind this is an explanatory *animation*, not a scientific *lecture*.)

What do we learn from this?

- It’s possible to measure the bending of starlight as it passes around the warped space of our Sun.

- It’s also possible to measure the warping of time—which sounds completely absurd until you run a simple experiment.

If you go to the top of a high building with an accurate clock in hand, you’ll see that the clock at the top of the building runs slightly faster than an accurate clock on the ground.

No way!? Try it.

Assuming that happens—which it will—what’s the reason? As we move away from the center of our planet—and from Earth’s center of mass (and Earth’s gravity source)—space and time are less warped.

So much for the idea that time is time and nothing can change it.

Einstein’s theory of general relativity also tells us something else about our universe: It has a beginning—and—it’s expanding.

From a hot and dense origin, according to Einstein, everything is expanding outward. And ... it’s been expanding since the very beginning.

Edwin Hubble (1889-1953) initially confirmed that theory with his analysis of galactic redshifts, and the orbiting telescope named after him has confirmed it with its observational findings.

There is a potential chink in Einstein’s armor, however. Scientists have determined that the universe is expanding even faster than the Man-of-the-20th-Century predicted.

Are the measurements wrong—or—was Einstein wrong? Does it make a difference, one way or the other?

Scientists think it does make a difference, so—supportive of Einstein's theory—we now have a “made-up energy” called “dark energy.” That “dark energy”—which NASA calls a “mysterious dark force that is pulling galaxies apart”—might account for the speedier-than-expected expansion of the universe.

Hand-in-hand with dark energy, scientists have also assumed there must be a never-before-seen type of “matter”—the word we use to describe the “stuff” of the universe—called “dark matter.” NASA tells us that “dark matter” is “thought to be the gravitational ‘glue’ that holds galaxies together.”

If scientists are correct about these two unknowns—“dark energy” and “dark matter”—how extensive are they (if they actually exist)?

You may not be ready for this answer, but here it is: These two unknowns likely make up 95% of the universe (“roughly 68%” is dark energy and “about 27%” is dark matter).

Wow! That’s a pretty substantial assumption for something we’ve never seen. On the other hand, it’s probably not a bad idea to give a genius like Einstein the benefit of the doubt.

Still ... it could be that Einstein was wrong, so physicists need to conduct major experiments to test his theories.

It wouldn’t be the first time that scientists tested the theories of the man who helped to usher-in the modern age. So far, every experiment, in the last 100 years, has proven Einstein right, but ... one never knows what today’s sophisticated technology and instrumentation will reveal.

We do know this, however:

- In 2011, a NASA experiment resulted in this press release: “Einstein was right again. There is a space-time vortex around Earth, and its shape precisely matches the predictions of Einstein's theory of gravity.”

- Findings by the Hubble Orbiting Telescope and the Chandra X-ray Observatory, in 2015, are helping to “narrow down the possibilities of what dark matter can be.”

In other words ... Einstein’s theory of general relativity—incorporating his concept of gravity—remains in tact.

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The embedded video, “Einstein 100,” celebrates the centennial of Einstein’s masterpiece, his Theory of General Relativity. It is a Windfall Films production for the Science & Technology Facilities Council. Its creators and narrator are:
EOIN DUFFY - Design / Animation
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Media Stream

Feynman, Dr. Richard P. - BBC Interview

Clip from BBC Horizon/PBS Nova, *The Pleasure of Finding Things Out*, Richard Feynman Interview (1981).

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