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Gravity Explained

I recently discovered we're in the midst of a scientific revolution — a new understanding of physics, gravity, and Einstein's theory of general relativity. This new understanding is being shared by dozens, perhaps hundreds, of scientists and thinkers worldwide. And it's following a path more like a new paradigm than the sort of academic "normal science" Thomas Kuhn lays out in his landmark analysis *The Structure of Scientific Revolutions*.

But this isn't really a new theory. It doesn't repudiate or contradict Einstein's core theory of the "curvature of spacetime". In fact, it makes it more complete — half of the effect is often ignored — and with this approach it's now much easier to understand and explain.

Here are the two core ideas of the theory:

1) According to both experiment and Einstein's theory, the apparent downward pull of Gravity is an illusion — what physicists call a *fictitious force,* perceived by observers who aren't conscious *they're* being pushed in the opposite direction. Strangely enough, the *real* force in our planet's gravitation is actually the earth's surface pushing us *upward*.
2) Space itself can stretch, shrink and change size — physicists call it *spacetime curvature*. And as space stretches, any matter or rigid object inside it stretches along with it. Depending on where it is and how it's moving, a rigid measuring ruler might *not* be the same length it was a minute ago — though *that may be far from obvious if everything else in the space nearby is changing size too*! Objects routinely stretch in ways most of us have never believed or conceived.

Once we understand, accept and combine these two ideas, a startling number of physical laws become simple and understandable.

First let's present a simple overview of what gravity is, and let's distinguish complex and confusing from simple and clear ways to explain it.

Relativity is Simpler Than We Thought

"Since the mathematicians have invaded the theory of relativity, I do not understand it myself anymore." — Albert Einstein

When we on earth throw a ball horizontally, we clearly see it curving downward. If we drop it from four feet above the ground, we see it briefly accelerate downward, faster and faster, until about a half second later it hits the ground and stops accelerating. Right?

But proponents of General Relativity say that according to the theory, the ball has no forces on it and that it's really moving at a constant velocity in a straight line through curved spacetime. How is that possible? What does it mean?

A standard general relativity curriculum or teacher might explain:
"The ball is traveling in a straight line at a constant speed — through curved 4-dimensional spacetime that's hard to visualize. That 4 dimensional 'straight line' is called a 'geodesic'. It follows a complex equation based on a mathematical object called a tensor with 16 coefficients and 10 independent variables. If you knew linear algebra and differential geometry, you might begin to picture it. But don't worry — everyone seems to find curved spacetime and 4 dimensional geodesics hard to visualize. Tomorrow we'll study the mathematics of Time Dilation, Proper Time, Excess Radius, and some diagrams illustrating Parallel Transport theorems that can prove this and help us visualize it."

But it's actually so much simpler:
*"Believe it or not, you, the floor beneath you, and the surface of the earth are all accelerating upward — in fact, outward, away from the earth's center — at 1 g. It's easy to measure, even using an app on your phone. Like Isaac Newton, as we unconsciously feel this force against our feet, we **think** it's an equal and opposite upward **response** to a downward pull of gravity. **But every experiment shows there is no downward gravity force** — just outward acceleration, originating from the earth and pushing us and everything around us upward!*

*"When we throw the ball, it **is** moving in an ordinary straight line. The moment we fully accept that we and earth's surface are continuously accelerating upward, it becomes obvious that a ball traveling in a straight line would appear to fall or curve downward that way."*

So the 4-dimensional geodesic isn't some mysterious result of complicated 4D math. It's really just a straight line, being viewed from an accelerating point of view. It's better seen simply as an acknowledgement that when an observer's point of view and position are changing over time, a simple straight line can look curved, so that before long we're imagining forces that aren't real.

Above we addressed the first point, the *fictitious force* issue. Details on the second point — how changes in the lengths of meters and seconds cause the upward acceleration — are described in Space Itself is Expanding — Gravity and General Relativity Explained.

The reason some physicists rarely explain this is, they don't quite believe it.
When humans hear "space is expanding" we picture galaxies flying apart, not objects changing size. That's true of most physicists too. Most don't consider that the rulers and rigid objects on their desks — and their desks themselves — could be growing bigger than they were a minute ago, or that the space that contains them has expanded. They certainly don't suspect that they, or the earth, might be twice as big as they were a few minutes ago.

And they're in good company. Even Einstein had trouble accepting the implications of his own theory of the expanding fabric of spacetime. In fact, he changed his theory twice and said his confusion about it led to the "greatest blunder" of his career.

As the quote above shows, Einstein openly worried that the powerful mathematical tools he and his colleagues had developed specifically to capture relativity had needlessly complicated and muddled it — even for him! — leading away from the fundamental ideas, simple descriptions of the theory, popular understanding, and further development of it.

Time Dilation, Space Dilation and Feynman

A typical physics curriculum offers a complex, less satisfactory summary of spacetime curvature focussing on Time Dilation — clocks slowing down — with no clear demonstration of how changes in the rates of clocks could cause objects to appear to be attracted to dense masses.

The renowned physicist Richard Feynman has been a key 'outside the box' thinker whose lectures point out that, along with stretching seconds and Time Dilation, the lengths of *rulers* change too — though he apparently didn't elaborate further on Space Dilation.

I've pursued this and found the approach provides a simple, geometric, causal explanation of how expanding space makes it look like massive objects appear to attract things near them — Gravity.

We treat Newton's gravitational constant G as a simple rate of accelerating expansion of a volume of 3D space V that contains matter, in proportion its mass M:

$d^2V/dt^2 = 4\pi GM$

where V is a volume of 3d space and G = 6.67e-24 meters^3/sec/sec /kilogram

As shown in Space Itself is Expanding, this formula leads directly to:

- a direct geometric and causal interpretation of Newton's G
- Newton's Inverse Square Law
- Gauss's Law of Gravity
- Einstein's Equivalence of Gravitation and Inertia
- Newtonian Issue of 'Action at a Distance' Resolved
- Gravity as a Fictitious Force Confirmed
- Experimental Confirmation Using iPhone App Data

A New Revolution in Physics, Relativity and Gravity: Why Now?

- ubiquitous gravity laboratories — personal motion sensors in the mobile revolution
- online social networks
- democratization and acceleration of peer review
- computer graphics and 3D animation
- decentralized, independent efforts
- a centennial celebration

During the recent General Relativity centennial in 2015, many authors and scientists wrote about the topic. Videos and blogs about Einstein and Relativity abounded. Their authors are still discovering each other online.

PBS SpaceTime created several relatively technical videos about Curved Spacetime and Gravity, including one summarizing the Gravity is a Fictitious Force idea. It's instructive to view the final segment and see the limits of explaining Gravity as a consequence of Time Dilation without Space Dilation. The narrator ultimately gives up, exasperating online commenters with a line from The Matrix: "Remember, no one can really see or draw spacetime. *There is no spoon*!"

In November 2015 I completed and published the results above in Space Itself is Expanding — Gravity and General Relativity Explained on Medium. It was a follow up of a previous article posted as a Facebook note, How Gravity Works.

A New Community
I recently learned that Ruud Loeffen's 2015 book Mind-blowing Gravitation: Gravitation Equals Expansion and web site refer and link to my Facebook article and my Medium piece.

Loeffen's book references dozens of physicists, mathematicians, computer graphic artists — both renowned and unknown — with diverse, compelling and often compatible physics discoveries. Through a corresponding online discussion group, Ruud has introduced me to dozens of thoughtful scientists and theories who have yet to be discovered in physics journals, that were published recently, along with relevant material from Einstein and others.

Einstein's iPhone: How Technology Simplifies Experiments
The iPhone accelerometer experiment in Space Itself is Expanding clearly shows the upward acceleration of the earth's surface, and the absence of downward gravity, in ways that couldn't be apparent to Galileo or Newton. As they measured the time between collisions using clocks, they didn't have an easy way to distinguish which objects were accelerating and which weren't.

In contrast, the acceleration of the iPhone when it's "at rest" and lack of acceleration when it's falling is decisive, and we don't have to wait for a solar eclipse or point a telescope at Mercury to see it. Gravity is an illusion and massive objects expand the space that contains them.

Technology effects how we do experiments, how often, how widely they're performed and how quickly they're confirmed. I strongly suspect that if Einstein had had an iPhone and could do these kinds of experiments with mobile accelerometers, it would have been clear a century ago that Gravity is a fictitious force. Our results confirming the expansion of space would have become widely understood relatively quickly and would by now be considered obvious.

Long before studies of stars during an eclipse, an iPhone app might well have become the first elegant experimental proof that gravity is an illusion — the main initial confirmation of his theory.

If Einstein had an iPhone, instead of being an obscure artifact for astronomers and rocket scientists, general relativity could have been much more widely understood, and modern physics may well have jumped ahead a hundred years.

How Einstein Empowered 21st Century Scientists To Complete His Theory
Along with the framework of general relativity, Einstein's greatest gift to today's scientists might be his long public history of stubbornly pursuing and testing his own strange ideas, but also recognizing blunders and changing his mind based on evidence.

As Kuhn points out, it's almost irresistibly tempting for students and scientific professionals to view scientific theories as authoritatively fixed and great scientists as infallible. But when we look at Einstein's history, it's clear that when you're actually discovering things, it doesn't work that way!

When we see Einstein, the originator and greatest authority on relativity, thinking hard about the ideas across decades — changing his mind at least three times and even reversing himself — we can't feel presumptuous or be timid when we question prevailing theories. Outsmarting Einstein by improving and completing his theories isn't an absurd or arrogant undertaking. It's our job.