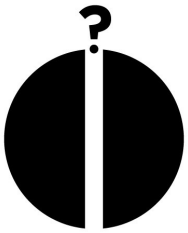
Feb 28, 2020

Guest Post for Kirsten Hacker's WordPress Blog



Galileo's Undone Gravity Experiment: Part 1

1. Introduction: The Great Unknown

> *How far into the foundations, when it comes, must the revolution penetrate?* —
>
> Thomas E. Phipps, Jr. : Harvard-trained physicist, 1986. [1]

What happens when a small body is dropped into a larger body with a hole through its center? If gravity is a force of attraction, then the small body will oscillate from one end of the hole to the other, in agreement with the theories of Newton and Einstein. Whereas if accelerometers tell the truth about their state of motion, nothing ever pulls the test object downward. It will therefore not pass the center. The apparatus needed to conduct this experiment may be called a *Small Low-Energy Non-Collider*. It was proposed by Galileo in 1632, but has not yet been done by humans. Why not?

We thus have two kinds of questions: 1) What happens when a small body falls into a hole through a large body? This is a *physics* ("hard" science) question. And 2) Why don't we find out? Why haven't humans explored this region of the physical world, right under our noses? This is a *sociological* ("soft" science) question.

Physics is regarded as a hard science because its statements about the world are often expressed as equations or graphs that facilitate clearcut comparison with empirical data. Figure 1, for example, tells us that most everything we know about gravity-induced radial motion traces back to evidence gathered *over* the surfaces of large gravitating bodies. Below the surface, inside matter, the path that extends through the center to the opposite side, is *unexplored territory*.

Unfortunately, most physicists just *pretend* to know what resides in this unexplored territory. They routinely invoke theories and authorities as substitutes for data. This is not how science is supposed to work. The fact of the data gap below the surface (red question mark) is a sufficiently compelling reason to insist on doing the experiment. Physicists cannot really be certain that the small body even passes the center, much less oscillates in the hole, without actually doing the experiment.

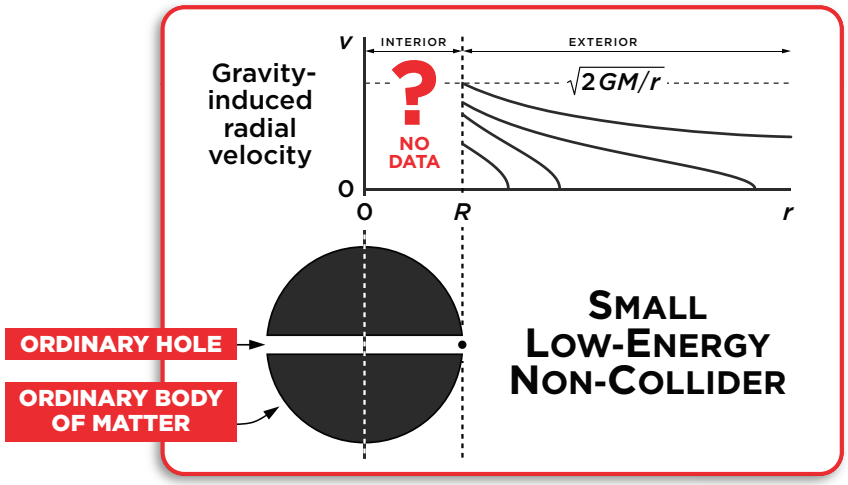


Figure 1: Humans have never seen what happens when a small body is allowed to fall to the center of a larger body. The big red question mark indicates where neither Newton's nor Einstein's theories of gravity have been tested. Representing the insides of all familiar bodies of matter, under our noses, it corresponds to the most ponderous half of the gravitational Universe. This unturned stone will remain in place to hide the truth for how much longer, exactly?

As suggested above, the non-oscillation prediction is correlated with a consistent belief in *accelerometer readings*, in contrast to the standard practice of only *selectively* (if at all) believing accelerometer readings. As indicated in Figure 2 (near the end of §2) a modern physicist's decision whether or not to believe an accelerometer is influenced by the presence, proximity and connection to large bodies of matter. It has to do with our conception of *gravity*.

To see the effect of this influence, we'll explore a circumstance in which it is totally absent. We'll do this by invoking the perspective of an imaginary civilization of technologically advanced beings who have no conception of gravity. This is possible for sentient beings who have evolved, not on an astronomical body of matter, but in a huge rotating space station far from any stars, planets or moons, in the outskirts between the galaxies. Inhabitants of this world care a great deal about their state of motion. They have accordingly developed an instinctive respect for accelerometer readings.

Earthians do not typically think in terms of accelerometer readings, which correlate with the *tactile*, flattening of their undersides. Instead we gauge our state of motion by *visual* evidence. Earth is huge compared to ourselves and seems visually "at rest." This causes us to unthinkingly follow our primitive predilection to regard Earth as *static*, in stark contrast to accelerometers all over the surface that say it moves. The answer to the sociological question: *Why don't we find out what happens?* is primarily that this ancient predilection overrides our empirical ideals.

A contributing factor to this answer is that the *culture* of academic physics is such that its members are *embarrassed* to admit that they have overlooked this "spot"—this

huge expanse of unexplored territory—right under our noses. Happily, in her blog and elsewhere, Dr. Kirsten Hacker has shared her perspective from experience as a 20-year member of the physics community—which corroborates my impression as an outsider—as to the fallibility of physicists and their inclination to succumb to peer pressure. (See also my *Correspondence With Professors.* [2])

With a critical eye, we will revisit the core of Einstein's work, which purports to justify the visually-based, unmoving Earth, "relativistic" perspective. Some advice from Newton indicates a possible advantage to the contrasting tactile, accelerometer-based perspective. An important *overlap* in perspectives concerns ideas of *spacetime curvature*, which Einstein had deduced with help from an analogy between gravity and uniform *rotation*. Explorers from the imaginary civilization alluded to above consiously experience gravity for the first time when they visit Earth. They agree with some of the logic by which Einstein deduced spacetime curvature, but they think a large part of Einstein's interpretation of his own analogy is upside down and backwards. So they flip it and then build on the analogy to deduce the existence of a fourth spatial dimension.

The dimension of *time* also plays an important role in our aliens' investigation. The primary measuring instruments of time are, of course, *clocks*, which serve also to measure *speed*. Einstein's theory of gravity (General Relativity, GR) makes definite predictions for how the rates of clocks vary because of gravity. Our aliens have reasons to be particularly suspicious of GR's prediction for the rates of clocks *inside matter*—especially at a massive body's center. The aliens are suspicious, not only because GR's prediction has not been tested, but because the pattern of clock rate variation correlates directly with predictions for the result of Galileo's experiment. In both GR and the aliens' model there is a tight *relationship* between gravity-induced clock rate variations and gravity-induced radial motion. It is therefore of great importance to *probe* this vast region of unexplored territory, to at last test and discover the nature of this relationship—especially, to find out whether it's Einstein's or the aliens' perspective that rings true.

The aliens' view concerning clock rates on and inside gravitating bodies traces back to their firm prediction that the test object in Galileo's experiment does not oscillate. Their newly hatched hypothesis of matter and gravity, in turn, leads to correspondingly radical cosmological consequences. They are now eager to tie their new discoveries and ideas concerning nearby bodies of matter to observations of the night sky and its spectacle of stars and galaxies.

Finally, the aliens apply their new appreciation of gravity to a nagging problem in both theirs and Earthians' world models concerning the *arrow of time*. Accelerometers seem to be saying—perhaps even *shouting*—that the otherwise enigmatic arrow of *time* is *interdependent* with the *arrows of gravity, space and matter:*

Going Up!

(See Figure 14, §9.)

2. Veneration of Accelerometers

> *The theoretical scientist is compelled in an increasing degree to be guided by purely mathematical, formal considerations in his search for a theory, because the physical experience of the experimenter cannot lead him up to the regions of highest abstraction. —*
>
> Albert Einstein, 1934 [3]

Einstein was a man of principle. He seems to have loved formal, abstract principles more than he loved the physical world. Formal principles served Einstein well as enduring marketing tools, the more so, the more vague and maleable they were. Among Einstein's inventions were the *Equivalence Principle*, *Mach's Principle*, the *Principle of General Covariance*, the *General Principle of Relativity*, and the *Relativity of Simultaneity*.

Of the Equivalence Principle, Okon and Callender have written "there are almost as many equivalence principles as there are authors writing on the topic." [4] In a book about Mach's Principle, 21 different interpretations are listed in a special index. [5] In a book about the *Relativity of Simultaneity*, renowned physics historian Max Jammer quotes Einstein's remark that it is "the most important, and also the most controversial theorem of the new theory of relativity." Jammer's 2006 book ends with his assessment:

> "Despite this unprecedented sophistication, the question of whether [any one interpretation of the Relativity of Simultaneity] is correct has not yet reached a final or generally accepted satisfactory solution." [6]

Is the spirit of Einstein laughing uproariously, or rolling in his grave?

The point is that Einstein's work permeates such a mucked up "understanding" of things, I think, that the actual facts of physical reality are likely to remain buried as long as Big Al retains his godly status. For the purposes of trying to get Galileo's experiment done, the most important example is the prevailing denial of clear-cut meaning of accelerometer readings. In the work of Einstein the problem traces back to his "Principles of Relativity." The *general* version asserts, in essence, that no matter what kind of motion an observer may be undergoing, she is justified to regard herself as being in a state of *rest*. If there's any motion taking place, it's *always* the rest of the Universe. That's what relativity theory is all about: the claim that it's *always* the other guy—*all* of the other guys who move. Me, I'm *always* at rest. ('Cuz I'm *special*. Insane? Yes!) Most of Einstein's high-falootin principles boil down to this nutty, obsessive denial of self-motion.

Einstein's perspective and the General Principle of Relativity are clarified by the following examples—first, involving *linear* acceleration, and second, involving *angular* acceleration. In his popular book on relativity, Einstein prepares his readers for an understanding of his theory of gravity by writing:

> It is certainly true that the observer in the railway carriage experiences a jerk forwards as a result of the application of the brake, and that he recognises in this the non-uniformity of motion (retardation) of the carriage. But he is compelled by nobody

> to refer this jerk to a 'real' acceleration (retardation) of the carriage. He might also interpret his experience thus: 'My body of reference (the carriage) *remains permanently at rest* [my emphasis]. With reference to it, however, there exists (during the period of application of the brakes) a gravitational field which is directed forwards and which is variable with respect to time. Under the influence of this field, the embankment together with the earth moves non-uniformly in such a manner that their original velocity in the backwards direction is continuously reduced. [7]

It should be noted that modern authors have sometimes criticized Einstein's appeal to a "*general* principle of relativity." But these criticisms do not go far enough, in my opinion, because they fail to root out the lingering troublesome effects of the idea that one can justify a claim of being "permanently at rest."

The troublesome nature of this claim becomes especially obvious, as Einstein attempts to extend it to not just *linear* acceleration, but also to *angular* acceleration (rotation). Einstein presents the scenario of an observer residing on a uniformly rotating disk. Even though the visual and tactile experience of this observer provides convincing evidence of his motion, Einstein argues that

> The observer on the disc may regard his disc as a reference-body which is 'at rest'; on the basis of the general principle of relativity he is justified in doing this. The force acting on himself, and in fact on all other bodies which are at rest relative to the disc, he regards as the effect of a [static] gravitational field. Nevertheless, the space-distribution of this gravitational field is of a kind that would not be possible on Newton's theory of gravitation. But since the observer believes in the general theory of relativity, this does not disturb him. [8]

Presumably, Einstein would not have been "disturbed" to suppose the existence of a second disk with an observer rotating in the opposite direction. One "not really" rotating observer says the whole rest of the Universe rotates clockwise. The other "not really" rotating observer says the whole rest of the Universe rotates *counter*-clockwise. It's crazy to think either of them has a logical leg to stand on. Both of these observers suffer the effects of motion (e.g., flattened undersides and slow clocks). Whereas observers at rest with respect to the rotation axes suffer no such effects. Surely logic dictates that the observers who suffer the *effects* of rotation are in fact rotating and the axis-observers, who suffer none of these effects, are not.

Was Einstein just trying to rack up points for boldness? Was he just testing his audience to see how gullible they are? Please understand that these proposals violate all common sense. Their "logic" requires a complete mental disconnect from physical reality, "up to the regions of highest abstraction." Slamming the breaks, hitting the gas, waltzing or break dancing—every instance of self-motion causes the whole rest of the Universe to move, while I remain "permanently at rest." That's the bill of goods this operator is trying to sell (even to himself).

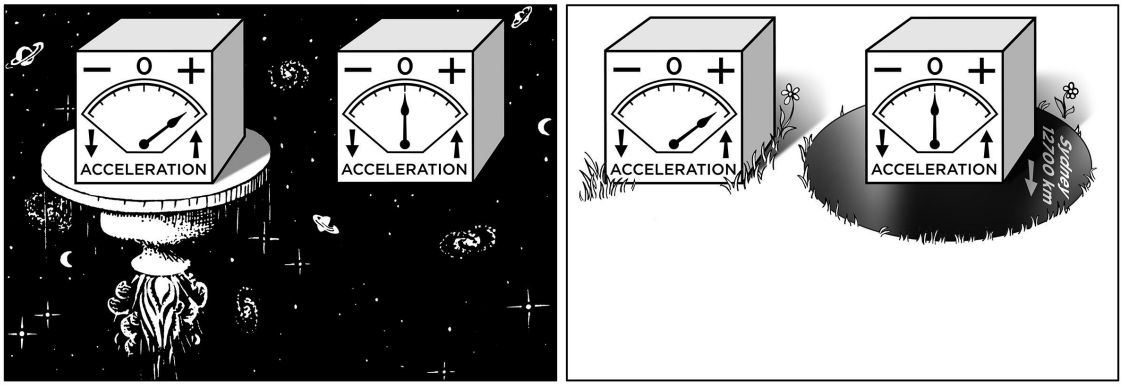


Figure 2: **Left:** It is widely understood that an accelerometer in outer space that is being accelerated gives a positive reading. If the accelerometer is not accelerating because it is not rotating and has no source of propulsion, then it gives a zero reading. **Right:** In the Newtonian framework, *this logic is discarded* when a large massive body is nearby because now one is supposed to imagine the existence of a mysterious force of attraction. The large body (planet) is presumed to be *statically at rest*, so the accelerometer giving the positive reading is presumed to be *not* accelerating (in contradiction to its reading). Whereas the accelerometer dropped into the hole, whose reading is zero, is presumed to be accelerating (in contradiction to its reading). In the general relativistic framework, the terms *acceleration* and *rest* are variably applied to any one of these accelerometers, depending on one's mathematical purpose. Having an abundance of mathematical options, to the general relativist, is a much higher priority than figuring out what's really going on, physically. *Our priority is to figure out what's really going on, physically.*

Ironically, for all the rational and valid criticism that may be inveighed against the founding principles of GR, because of its well known assortment of empirical successes, the final theory stands as our best model of gravity. Some of these successes need more careful scrutiny—as Dr. Hacker has often pointed out. But the more secure ones—involving light paths, clock rate variations, and orbiting bodies within the Solar System and some distant astronomical bodies as well—are not so clearly, if at all, predicted by rival theories. GR stands, arguably, unopposed by any serious alternatives.

Furthermore, it may be objected that believing accelerometers is not likely to yield a better theory because it already leads to the seemingly preposterous idea that Earth and all massive bodies are perpetually expanding. Our aliens do have cogent answers to this, among other seemingly fatal objections to the idea that accelerometers tell the truth. But all the talk and all the mathematical analysis in the world is not going to settle the matter, as would a quiet glimpse at the workings of Nature itself. Best for everyone to just shut up so that we might hear what physical reality has to say, to at last listen to that trampled-on inner physical world that has not yet been given its rightful, central place in the discussion. Meanwhile, as we await that fateful silent moment, let us press on, doing what we can to make it happen.

3. Rules, Principles, and Physical Reality

RULE I

We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.

To this purpose the philosophers say that Nature does nothing in vain, and more is in vain when less will serve; for Nature is pleased with simplicity, and affects not the pomp of superfluous causes.

RULE II

Therefore to the same natural effects we must, as far as possible, assign the same causes. —

SIR ISAAC NEWTON, 1686 [9]

Members of the imaginary alien civilization that we referred to in the previous sections live in the rotating world of Roton. We call them Rotonians. As they see it, life in their cylindrical world is made possible by the *absoluteness* of its rotation, as indicated by various observations. Among the most important of these observations are accelerometer readings. Without knowledge of the existence of Isaac Newton, when Rotonians encounter an astronomical body (planet) for the first time, they *instinctively* abide by the *Rules* copied above. Which means that they interpret the accelerometer readings found around the globe as indicating that matter is accelerating itself outwardly; that *matter is not static, it is an inexhaustible source of perpetual propulsion*. Since the *cause* of the non-zero readings on accelerometers attached to *Roton* is absolute acceleration, this is most likely the cause of the readings found on accelerometers attached to *planets*. To suppose otherwise would be to "affect the pomp of superfluous causes." So they reason—knowing, of course, that they need more evidence to prove it.

Before setting the scene of Rotonian physics and technology which inspires them to probe the Universe and leads to their fateful journey, it should be pointed out that the change in perspective gained by doing so could well have dawned on any Earthian physicist who deigned to objectively consider the facts.

The two *Rules of Reasoning in Philosophy* opening this section might have sufficed to provide the needed inspiration. Einstein's rotation analogy, which relates certain facts and experiences on a gravitating body with those of an observer on a uniformly rotating body, may have provided the inspiration. Einstein's *Equivalence Principle*, which is itself a kind of analogy, might independently have provided the inspiration. Combining these analogies with Newton's Rules makes the Rotonian assessment nearly inescapable. Yet Einstein and his followers have assiduously escaped it.

Almost as an obsession, Einstein sought

> A theory in which all states of motion of coordinate systems are—in principle—equal. . . . We want to use this equivalence as a basis under the name of "general principle of relativity." [10]

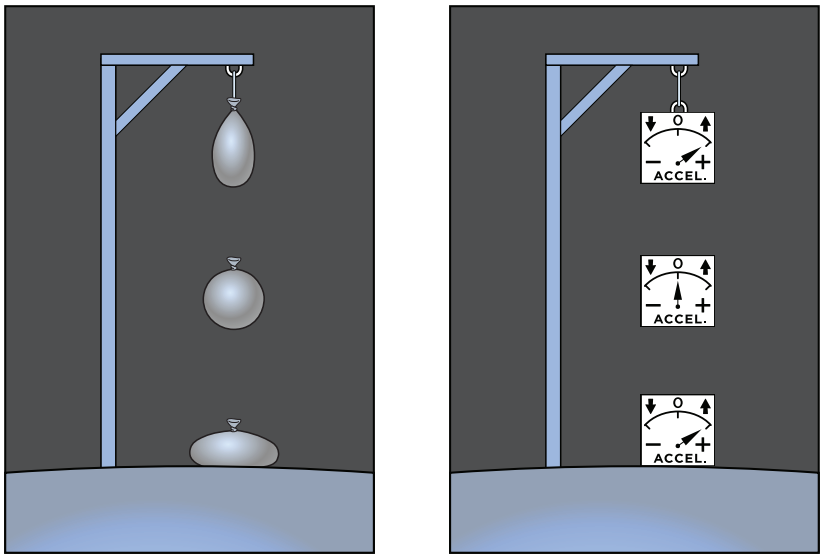


Figure 3: Uniform vs. non-uniform motion. **Left:** Any soft, yet elastic body suffices as a crude accelerometer. When moving uniformly, it retains a minimally stressed shape. When accelerated, its shape is distorted (stretched or squished) depending on whether the force is applied from "below" or "above"—i.e., whether it is being pushed or pulled. **Right:** An "analytical" accelerometer merely translates the stresses on internal springs or pendulums into displayed quantitative data.

If an observer's state of motion is *uniform*, she will float without *feeling* any physical stress (tension or compression): no flattened undersides or stretched oversides. Whereas, if an observer's state of motion is *accelerated* (pulled from "above" or pushed from "below") she will in fact *feel* it as such. The observer (or balloon—see Figure 3, for example) will in fact suffer one-sided stretching or squishing. Why would anyone in his right mind want to say that these obviously different states of motion are "equal" when the *effects* are so clearly different?

Because, perhaps, it perpetuates the primitive delusion that matter is made of static chunks of stuff. Insofar as Einstein's general principle is sellable at all, perhaps it's because virtually all Earthians suffer from the same delusion. And yet Einstein's marketing tools contain tantalizing invitations to flip the gestalt switch that he seems to be straining, with all his powers of denial, to *not* flip. Einstein is confronted with plenty of evidence that he is awkwardly holding the switch upside down. His audience cheers because Big Al is the star of the show. Both performer and audience are unmoved by the flagrant violation of Newton's Rules unfolding before them, being bought and sold as the unquestioned "fact" of static matter.

Ironically, in the vast and sometimes colorful literature on Einstein's Equivalence Principle (hereafter, EP) we sometimes find authors who playfully suggest, in effect, believing accelerometer readings. We'll consider three examples. The principle was originally proposed to explain the empirical fact that all falling bodies—whether they are heavy, light, or composed of any chemical species of matter—*appear* to have the same

downward acceleration. The equal falling of all bodies is explained not as a consequence of equal *downward* accelerations of the falling bodies, but as the "equivalent" *upward* acceleration of the ground.

Sam Lilley thus defines the EP: "*There is no means of distinguishing between the effects of constant gravity and those of a constant acceleration of the observer.*" He continues:

> So the simplest interpretation of what we observe would be to say that *we* are accelerated . . . If we insist on maintaining that we are [at rest], we have to *invent* this distinctly odd force to explain what we observe about things falling.
>
> Could the [attractive] force of gravity be . . . illusory? It looks as if there may be *some* sense in saying that the force of gravity is an illusion that arises because we deny being accelerated when we really are. [11]

In his remarkable book, *Relativity Visualized*, L. C. Epstein expressed the idea similarly: "Einstein's view of gravity is that things don't fall; the floor comes up!" [12] And J. Richard Gott III explains:

> Einstein proposed something very bold—if the two situations [accelerating in a rocket ship and a state of rest on a gravitating body] looked the same, they must *be* the same.
>
> If gravity and accelerated motion were the same, then gravity was nothing but accelerated motion. Earth's surface was simply accelerating upward. This explained why a heavy ball and a light ball, when dropped, hit the floor at the same time . . . The floor (Earth) simply comes up and hits them. What a remarkably fresh way of looking at things! [13]

Just as Lilley and Epstein ultimately discard this line of thought, Gott backs out by claiming: "The only way the assertion could make sense is by considering spacetime to be curved." But adding spacetime curvature to the explanation is not sufficient to validate the claim: "the floor (Earth) simply comes up." In Einstein's theory the curvature of simple cases like this is patently *static*. The equation from Einstein's theory that best describes gravity around the Earth or Sun is Karl Schwarzschild's well known exterior solution, which represents a spherical body's *static* field.

To claim validity to both ideas: "the floor comes up" *and* "the geometry of a gravitational field is *static*" is to defend a blatant contradiction. We might call it *Trumpian physics*. The only purpose served by trying to have it both ways is to *confuse* anyone not wise enough to see that doing so obscures the truth, thereby providing a foggier hiding place. Rotonians think that in physics, as in the rest of the world, there *is* such a thing as truth. In physics it is *always* best to seek and clearly expose the truth, *never* to shirk from or hide it behind a curtain of foggy abstractions. Properly functioning accelerometers are utterly truthful instruments. One's undersides are flattened or they are not. This is an

absolute physical fact. It arises because of the in-your-face *difference*, the stark *inequality* between accelerated and uniform motion.

Unfortunately, the assertion of a physical difference between zero and non-zero accelerometer readings (unflattened and flattened undersides) was seen by Einstein as an "epistemological defect." He therefore tried to convince himself and his audience that he was doing everyone a favor by *fixing* the defect. *Clarity* was not one of Einstein's dominant characteristics. He preferred, rather, the comforting mudfog of his principles. In the following passages we witness Einstein's defense of his principles and corresponding flagrant denial of the truthfulness of accelerometer readings:

> The theory sketched here overcomes an epistemological defect that attaches not only to the original theory of relativity, but also to Galilean mechanics, and that was especially stressed by E. Mach. It is *obvious* that one cannot ascribe an absolute meaning to the concept of acceleration of a material point, no more so than one can ascribe it to the concept of velocity. Acceleration can only be defined as *relative* acceleration of a point with respect to other bodies. [14] (My emphasis.)

The above was published in 1913. The following is from 1914:

> One would try in vain to explain what it is that one should understand by the pure and simple acceleration of a body. One would succeed only in defining the *relative* accelerations of bodies with respect to each other . . . We base our mechanics on the assumption that a force (cause) is necessary for creating an acceleration of a body, ignoring the fact that we are unable to explain what it is that we are to understand by "acceleration," precisely because only relative accelerations can be an object of perception. [15] (My emphasis.)

Were they socially sensitive sentient beings, every accelerometer in the Universe would *cringe* and forcefully object to this absurd disrespect from Earth's illustrious "genius."

4. Rotonians

> *In the case of the rotation of the coordinate system: there is* **de facto** *no reason to trace centrifugal effects back to a 'real' rotation. —*
>
> Albert Einstein : Letter to correspondent, A. Rehtz, 1953. [16]

4.1 Context: Historical, Physical, Imaginary

Written in 1953, the above quote (from a paper by John Norton) tells us that Einstein's views on motion, or its alleged absence, changed little, if at all, from 1913 to nearly the end of his life in 1955. As though a physicist has the *option* to trace centrifugal effects back to a *fake* rotation, or some such baloney. Following a quote from the same letter,

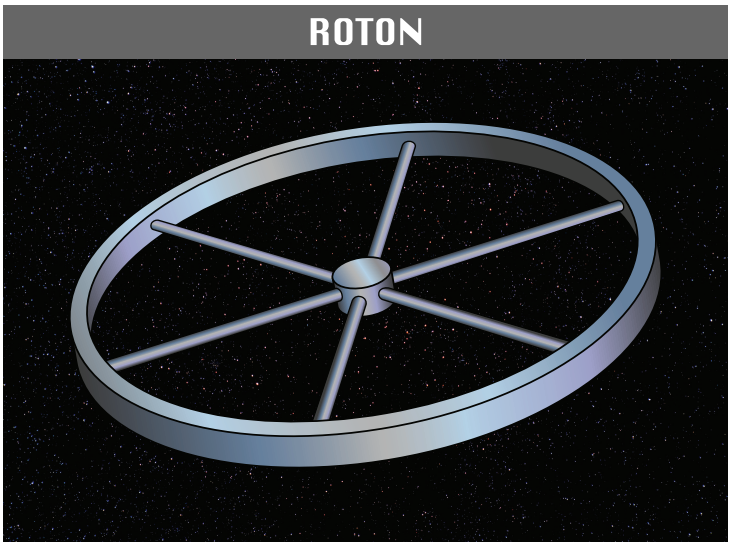


Figure 4: Rotonians reside primarily on the inside wall of the outer circumference of the gigantic rotating world of Roton. Being about twice the diameter of Earth's Moon, Roton's rotation period of one hour produces an acceleration the same as that at Earth's surface. We do not concern ourselves with the origins of Roton, nor its means of sustenance. We are satisfied that it is an at least *possible* living space, and that the world view conceived by its inhabitants over many thousands of years would likely be—in certain key respects—much different from that of humans, who evolved on planet Earth.

physics historians Juergen Renn and Tillman Sauer state: "If the acceleration field of such a rotating frame of reference could be interpreted as a gravitational field, then rotation could be conceived as a state of rest." [17] Based on the assumption that Earth and its gravitational field are essentially *static*, Einstein claims that the non-zero accelerations experienced by *rotating* observers, are equally indicative of a *state of rest*.

By contrast, Rotonians instinctively regard sets of non-zero accelerometer readings found in both systems as indicating equally absolute accelerations. The motion is just as *real* in both cases, even as they exhibit distinct differences. Rotation is of a material body immersed against a largely *discontinuous* background that doesn't rotate. But, as the Rotonians will soon come to discover, gravitating bodies affect their surrounding backgrounds in a decidedly *continuous* way. Ultimately, Rotonians will regard both kinds of motion as *stationary*, hence they are analogous, but they realize the importance of distinguishing between them, i.e., where the analogy breaks down.

Rather than get any further ahead of ourselves, let's build up the Rotonian perspective step by step, to clarify how they come to see the similarities and the differences between rotation and gravity.

To any Rotonian the assertion that rotating observers can claim to be *at rest* is wildly preposterous. Rotonians nevertheless see the silver lining in Einstein's rotation analogy because it echoes their own discoveries bearing on the possible *utility of non-Euclidean geometry*. So important was this connection that science historian John Stachel referred to

it as "the 'Missing Link' in the History of General Relativity." Stachel wrote:

> Einstein's treatment of this problem is of interest . . . because it seems to provide a 'missing link' in the chain of reasoning that led him to the crucial idea that a nonflat [i.e., non-Euclidean] metric was needed for a relativistic treatment of the gravitational field. [18]

The contrasting ideas emerging before us—only one of which stands to be vindicated by unequivocal evidence—are illuminated by following this *missing link* along the chain to its natural conclusion. On one hand is the perspective of a young planet-based civilization, represented by its iconic genius theoretician. On the other hand is the perspective of the "off-world" accelerometer-believing Rotonians. The former (Einsteinians) are deeply affected by their primitive impressions of living on a static chunk of stuff. Seeing some similarity between their gravitational experience and the effects found on a rotating body, their representative (Einstein) proposes that the rotating body can also be seen as statically*resting*. Whereas the latter (Rotonians) are convinced of the absoluteness of rotational motion. When they discover similar effects on the first astronomical body they encounter, Rotonians ascribe these effects to *motion*, as they always have.

The stage is clearly set for a showdown. Rotonians have come to the same juncture as the Einsteinians, where everyone agrees that the well worn (flat) geometry of Euclid has limits that may be usefully transcended by introducing the idea of *spacetime curvature*. Einstein's curvature is static and its *cause* is unknown. By deducing that curvature is *caused by motion*, in contrast, the Rotonian view stands as a potential advance in our understanding of gravity. The history leading to Einstein's perspective is well known. In what follows we add some detail to the story of how the Rotonians have come to this juncture, beyond which, only the truest of the two conceptions (static or moving) will survive. Let's therefore begin with a few details of Rotonian history and the physical parameters of their world.

Rotonian origins are only partly known. Their evolution spans millions of years, perhaps not unlike human Earthians. Unlike Earthians, however, Rotonians never had an external *Sun* to worship. Their internal energy source remained entirely obscure until the recent era in which they've realized the possibility of finding some answers by scientific research. Rotonians have deduced that the structure of Roton must have been built by an absent, most likely distant civilization that "planted" the ingredients needed to promote their emergence in this cosmic locale, as an *experiment*, to see what may grow and evolve, without further interference.

Fast-forwarding to a stage of mathematical, scientific, and technological development similar to the early part of Earth's third millennium, we reflect on a few of the Rotonians' key discoveries of the previous few thousand years. When Rotonians' understanding of geometry and mechanical science were comparable or superior to Earth's Newtonian era, they measured the size and motion of their world. We will use this data to quantify key facts having to do with later developments involving the speed of light, the rates of clocks, and how these developments mesh with Rotonians' mathematical explorations into non-Euclidean geometry.

4.2 Size and Motion Specs: Accelerometers, Clocks, and the Speed of Light

By happy coincidence and convenient comparison with the experience of human beings on Planet Earth, Roton is found to have an angular velocity ω, which makes its rotation period $P_{\text{ROT}} = 2\pi/\omega_{\text{ROT}} = 1$ hr (= 3600 seconds) and provides a rim acceleration the same as that at Earth's surface:

$$g_{\oplus} = 9.8\,\text{m}\,\text{sec}^{-2} = a_{\text{ROT}}. \tag{1}$$

From these specifications, by rearranging the acceleration equation, $a = R\omega^2$, we can determine the size of Roton:

$$R_{\text{ROT}} = \frac{a_{\text{ROT}}}{\omega_{\text{ROT}}^2}. \tag{2}$$

The cylinder's radius is about $\frac{1}{2}$ that of Earth, which is about twice that of the Moon:

$$R_{\text{ROT}} = 3.217 \times 10^6 \text{ meters}. \tag{3}$$

From the radius and the angular velocity, $\omega_{\text{ROT}} = 0.001745$ radians sec^{-1}, we find the rim speed:

$$v_{\text{ROT}} = R_{\text{ROT}} \times \omega_{\text{ROT}} \approx 5615\ \text{m}\,\text{sec}^{-1}, \tag{4}$$

which is about $\frac{1}{2}$ of Earth's escape velocity $V_{\oplus} = \sqrt{2GM/R_{\oplus}} \approx 11,180\ \text{m}\,\text{sec}^{-1}$.

Earthians' world view has been profoundly shaped by observing the distant stars and galaxies. So too for the Rotonians. Their industry of advanced optical instruments has yielded several observatories that hover beyond the structure of Roton in the vacuum of space, which facilitates impressive optical resolution. When the distant objects are viewed from resting locations such as Roton's projected axis, their positions on the sky remain essentially fixed. This natural wonder piques the Rotonians' curiosity no end.

The rotation axis of Roton is the only place where accelerometers attached to the structure read zero. The readings of all other Roton-mounted accelerometers are greater in proportion to radial distance. The maximum acceleration is thus found on the outer wall—the inner surface of which is where the vast majority of Rotonians live. To these Rotonians the visual positions of distant bodies cycle once per hour. This fact has permitted, among other things, determining the *direction* of their spinning motion. This direction also becomes evident, of course, when unrestrained objects fly off on tangents.

Long ago Rotonians sorted their way through a rough equivalent of Earth's 19th century science. Around the same time, Rotonian mathematicians made great strides in higher-dimensional and non-Euclidean geometries. Similar advances in understanding electromagnetism and optics inspired Rotonians to build an optical relay path that

extends around Roton's circumference. This represents not only an advance in their communications system, it also served as a large-scale confirmation of results obtained with similar, smaller scale devices—known to Earthians as *Sagnac interferometers*.

The key characteristic of these devices is that they serve to measure deviations from the base speed of light ($= c$) with respect to rotating observers in opposite directions of propagation—i.e., with or against the rotation direction.

It so happens that the development of Rotonians' atomic physics was well beyond Earthians at the corresponding time. Specifically, they had already invented fully functional, nano-second-accurate atomic clocks. Therefore, Rotonians were able to measure propagation-time differences, not just as optical phase shifts—as in the smaller Sagnac interferometers—but as fractions of a second differences in light-transit time. The difference for light paths traversing opposite directions around the rim of Roton comes out as

$$\Delta t \approx \frac{2lv}{c^2} \approx \frac{1}{400,000} \text{ sec.} \tag{5}$$

where l is Roton's circumference and v is the tangential speed of Roton's rim. By virtue of this measurement all Rotonians know that the speed of light with respect to themselves in the direction of rotation is $c - v$ and in the opposite direction, it is $c + v$. They have no hangups about wanting this speed to always $= c$. Unlike Earthian physicists, Rotonian scientists do not worship symmetry. It would never occur to them to insist that space is isotropic, except perhaps for observers who find the cosmic background radiation and redshifts of distant galaxies to be isotropic. We'll get back to such cosmological considerations later. For now, the key point is that a central feature of the *knowledge and experience* of every Rotonian—built up over thousands of years—is the *fact of absolute motion*. "Relativistic" concepts of motion were inconceivable. No Rotonian in their right mind would ever dream up something so absurd as a *theory* of relativity.

For example, consider how Rotonians assess the light from distant sources. For a given Rotonian (whose telescope is fixed to the rim) the spectra of distant objects cycles over the course of an hour, yielding a cosine curve across the median, shifting from red to blue and back and repeat. (Maximum amplitude for objects on the plane of rotation.) To the Rotonians it is obvious that these frequency shifts are due to their own speed, which gets added to or subtracted from the base speed of light, as expressed in the classical Doppler formulas. This was also the view of most physicists in Earth's late 19th and early 20th centuries, including Hendrik Antoon Lorentz, whose eponymous "transformations" are routinely (and ironically) regarded as expressions of the relativistic perspective.

With the ascending popularity of Einstein's relativity theories it has now become politically incorrect (on Earth) to make the simple common sense observation: *I move around; therefore the speed of light with respect to me is constantly changing.* The contrary interpretation is mud-foggily *principled*, to be sure. It just doesn't make sense. Even while rotating, Einstein says, we are supposed to deny that we move; we are supposed to say the speed of light with respect to ourselves is always equal to c. Rotonians see

this as silly, as a misguided denial of reality. It's actually worse than silly. Being infected by relativistic dogma for more than a century, Earthians are now suffering from its perniciousness. *PhDizzix* is an entertainment industry and *Reality* is a TV sit-com.

4.3 Michelson Interferometer; Implications for Spacetime Curvature

But there's a silver lining. The next and crucial step toward glimpsing the possible applicability of non-Euclidean geometry to the physical world arose due to Rotonians' invention and implementation of another kind of optical device: The equivalent of an Earthian *Michelson interferometer*.

In Earth's late 19th century it was widely conceived that light propagates through a universal medium called the *ether*. Rotonians conceived space in a similar way. Initial assessments suggested that the hub of Roton was at rest in this ether, whereas all of Roton beyond the axis rotates though it, with measurable effects. We cannot go back to see how Earthian physics might have evolved differently if the Sagnac interferometer had been invented before the Michelson interferometer. But this is how it happened on Roton.

It was thought by both Michelson and his Rotonian counterparts that the new interferometer, with its cross- (or L-) shaped light path would suffice to measure the difference in light speed by comparing its propagation in perpendicular directions: Forth and back parallel to their direction of motion, and forth and back perpendicular to their direction of motion. The measurement has often been likened to a comparison of the time taken for identical swimmers to travel the same distance with respect to markers on a river bed, cutting across the current direction versus the path up and downstream, against and with the current. In this case the cross-current swimmer makes slightly better time than the upstream-downstream swimmer. An analogous result was expected for light.

It is worthwhile to analyze the analogy in some detail. (See Figures 5 and 6.) If the swimmer's speed through water is analogous to light propagation speed through ether (space) it never changes. We therefore denote this speed as a constant $= c$. The river current speed is analogous to our speed through the ether, so we denote it as $= v$.

Figure 5 shows the cross-current path, with its geometrical symmetry for opposing directions. Also shown is the gross *a*symmetry for the parallel, upstream-downstream path. The *time* required to swim the designated path is the ratio, in each case, of the ground length, L, divided by the corresponding speed. Sparing the algebra, we simply display the range of times in descending order, left to right, where the subscript symbols indicate the following. ($T_\uparrow$): One leg *against* the current. ($T_\parallel$): *Average* of forth and back *parallel* to current. ($T_\perp$): One leg forth and back *perpendicular* to current. ($T_\circ$): If the current speed $v = 0$. And ($T_\downarrow$): One leg *with* the current.

$$T_\uparrow : T_\parallel : T_\perp : T_\circ : T_\downarrow \quad \rightarrow \quad \frac{L}{c(1-\frac{v}{c})} : \frac{L}{c(1-\frac{v^2}{c^2})} : \frac{L}{c\sqrt{1-\frac{v^2}{c^2}}} : \frac{L}{c} : \frac{L}{c(1+\frac{v}{c})} \,. \tag{6}$$

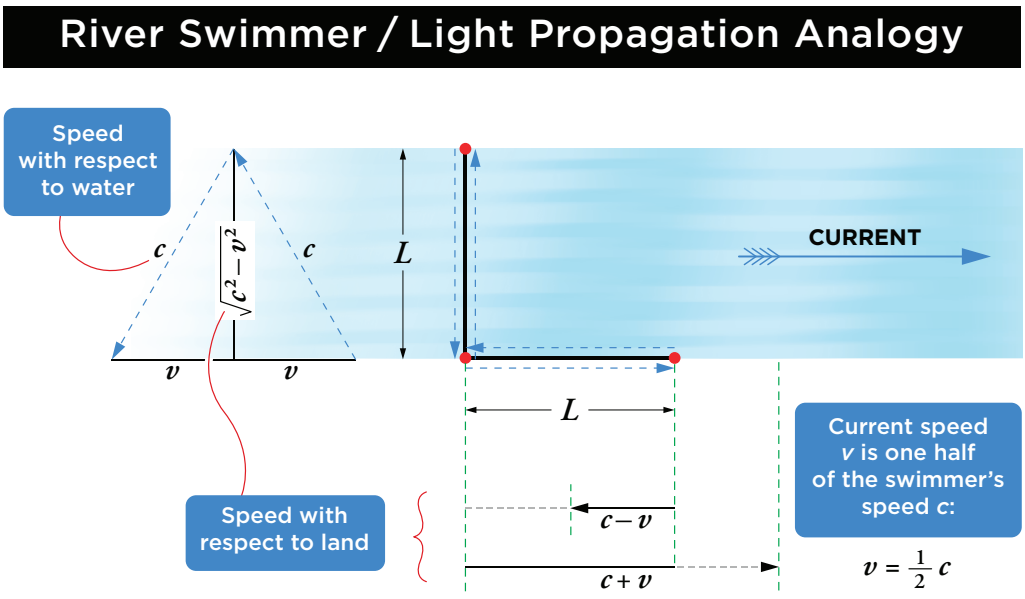


Figure 5: A swimmer whose speed with respect to the water is always $= c$ swims perpendicular paths with respect to the shore (between red dots) through a river with current speed $v = (1/2)c$. The upstream/downstream path takes a little bit more time than the path cutting directly across the current.

The table in Figure 6 shows numerical magnitudes corresponding to these relations, assuming that $L = 100$, beginning with the speed ratio $v/c = \frac{1}{2}$, and two smaller ratios. The idea is to illustrate the significance of *first order* speed ratios v/c, as compared with *second order* speed *squared* ratios v^2/c^2. This is also the motivation for the color differences: red, blue. Examples of prominent first order effects are Doppler shifts and Sagnac-like phase shifts, or propagation-time differences. Whereas second order effects are significantly more subtle, such as time dilation and space warpage.

Albert Michelson was a very competent experimentalist. The results he obtained with his interferometer in 1887 were improved upon by him and many others over the ensuing 133 years. Rotonians are also competent experimentalists, and found the same results. If light propagation were completely analogous to our river-swimmer scenario, the experimenters would have established this using their Michelson interferometers, which were delicate enough to detect a phase (or time) shift between parallel and perpendicular light paths. Michelson thought he was going to measure the Earth's speed around the Sun and the Rotonians thought they would find another way to measure their rotation speed. But the famous fact is that, in both cases, the results were *null*.

Since the Rotonians had already measured the difference in light speed in opposite directions with atomic clocks, they were puzzled to explain these new results. A fact that now requires more focused attention is the Rotonians' discovery that *the speed of rotation affects the ticking rates of their atomic clocks*: The faster the rotation speed, the slower the clock rate. By comparing the elapsed times of clocks on the rim with those of a clock at

ASSUMES: Distance L = 100 and c = 1	1-LEG AGAINST CURRENT	AVERAGE $\frac{1}{2}\langle$ UP + DOWN $\rangle$	1-LEG PERPEN-DICULAR	IF CURRENT SPEED v = 0	1-LEG WITH CURRENT
Path Time Symbol	$T_{\uparrow}$	$T_{\parallel}$	$T_{\perp}$	$T_{\circ}$	$T_{\downarrow}$
Algebraic Expression	$\frac{L}{c(1-\frac{v}{c})}$	$\frac{L}{c(1-\frac{v^2}{c^2})}$	$\frac{L}{c\sqrt{1-\frac{v^2}{c^2}}}$	$\frac{L}{c}$	$\frac{L}{c(1+\frac{v}{c})}$
Time: Given $\frac{v}{c} = \frac{1}{2}$	200.000	133.333	115.547	100.000	66.667
Time: Given $\frac{v}{c} = \frac{1}{10}$	111.111	101.010	100.504	100.000	90.909
Time: Given $\frac{v}{c} = \frac{1}{100}$	101.010	100.010	100.005	100.000	99.009

Figure 6: Path times involving *second* order speed ratios are much closer to the current speed $v = 0$ time L/c than the times involving *first* order speed ratios. Note that one factor of $\sqrt{1 - v^2/c^2}$ separates the perpendicular path time from the $v = 0$ result and also the upstream-downstream result—in the first case in the numerator, in the second case in the denominator.

the hub, and at various locations along the spokes (and parked just outside of Roton's structure) they determined that moving clocks tick slow by the factor $\sqrt{1 - v^2/c^2}$.

The Rotonians therefore reasoned: If motion through space has an effect on clocks (time) perhaps it has a corresponding effect on measuring rods (space) and material bodies in general. Specifically, if the leg of the interferometer parallel to the direction of motion contracted by the same factor $\sqrt{1 - v^2/c^2}$ (i.e., if its physical length were not L, but $L\sqrt{1 - v^2/c^2}$) then the travel times in perpendicular directions would be *the same*. This would explain why the experiment yielded a null result. Back in the 1890s Lorentz and Fitzgerald proposed exactly the same possibility. [19]

Einstein interpreted the results on Earth as indicating the superfluousness of the ether and as support for his "relativistic" assertions that all inertial observers can justify claiming to be at rest. By contrast, since the Rotonians already know for a fact that they move through space, they regard the Lorentz-Fitzgerald contraction not as a *relative* effect, but as an *absolute* effect. They combine this new evidence with their mathematical explorations, at that time, that also imply a kind of malleability to space. The limiting speed of light affects measurements of both space and time. Most importantly, temporal geometry is not strictly Newtonian, spatial geometry may not be strictly Euclidean; and the *cause* for both kinds of deviation is *motion*.

Combining the physical evidence with the theoretical possibilities, Rotonians contemplate the possibility of *curved spacetime*. One of the consequences of this curvature—at least with regard to the rotating structure of Roton—is that length standards are evidently affected by motion in such a way that *two-way* light paths—regardless of their direction—yield the same *average* (base) speed of light ($= c$). This hypothesis explains

the null experimental results and shows some promise of facilitating other discoveries.

Unbeknownst to Rotonians at the time, a similar line of thought would later be found to apply to *volumetric* space, as influenced by huge concentrations of matter, with which they had not yet had any experience. Lots of ink has been spilled on Earthian interpretations of these matters. Although a bandwagonesque kind of consensus has emerged, the foggy weaknesses in the foundations remain—as indicated by the index of 21 Mach's Principles, innumerable "Equivalence Principles," and the unresolved status of the Relativity of Simultaneity, among many other lingering quandaries.

In what follows we will continue to build on what Einstein and the Rotonians agree about. As discussed by Stachel in his *Missing Link* paper, rotation is correlated with effects on clocks and measuring rods of the same magnitude, suggesting that deviations from the Newtonian-Euclidean world view can be usefully accommodated by non-Euclidean geometry. Physical experiments in which the limiting speed of light plays a role suggest that space and time are in some sense *interdependent*. This justifies thinking of them as a consolidated *spacetime*. We will also continue to emphasize where Einstein and the Rotonians disagree: statically resting chunks of stuff *vs.* absolute motion, as the *cause* for these "metric" effects.

5. Voyage to Planet Earth

Earthians have lived their entire lives on a 5.97×10^{24} kg ball of matter. It is probably impossible to overstate the influence of this fact on their conceptions of motion. Having a starkly different set of primal experiences, Rotonians have for centuries been building up a space exploration program which is now so advanced that it is far superior to Earthians' early 21st century NASA program. Breakthroughs in medicine, physiology and cryogenics have recently enabled the possibility of putting living organisms, including Rotonians themselves, into stasis for hundreds of years with no ill effects upon reawakening.

Rotonians have therefore taken the bold step of sending a probe of explorers to investigate the far-off points of light. As planned, the centuries-long journey is essentially uneventful until the fateful reawakening is triggered by proximity to an astronomical body of matter. With lingering grogginess from their stasis, the crew scratch their eyes to see the reflected light from a huge ball of matter in the far-off distance. Their rockets are off, and yet their measurements indicate that the ball is accelerating straight toward them. Its acceleration and speed are increasing in a well defined way, which at first arouses curiosity, but then turns to alarm as the fast-approaching orb begins to fill their field of view. Rotonians are in a state of untold shock and bewilderment, as they contemplate what kind of huge rocket must be powering the sphere from its far side. What in the world could propel this gargantuan body with such extreme rapidity and persistence?

Rotonians avoid a catastrophic collision in the nick of time by blasting their rockets toward the approaching body, to gradually match the speed, acceleration and direction of the ascending surface. With a great sense of relief, they navigate a soft landing. *What a mind-blowing experience!* As the Rotonians explore the surface and communicate with the

natives (from whom they learn that this ball is a *planet* called Earth) they discover that there never was any far-side rocket. Accelerometers placed at any and all locations on the sphere's surface indicate that it perpetually accelerates itself upward in *every* direction! Matter itself, evidently, is an inexhaustible source of perpetual propulsion. What else are the Rotonians to make of the starkly observable facts?

Rotonians are unconvinced by the accelerometer-disbelieving, superstition-harboring Earthians who claim their planet to be a *static* thing. Rotonians soon learn that the natives maintain a variety of schizoid views about a magical mystery force they call *gravity*. This allegedly attractive force of Nature is sometimes claimed to cause acceleration at-a-distance without yielding a non-zero accelerometer reading on the object that is magically made to accelerate. The non-zero readings found all over the surface are sometimes mockingly accepted as telling the truth (Equivalence Principle)—which would "explain" why falling objects exhibit zero accelerometer readings. But this vaguely entertaining treatment of gravity by Earthians only makes their schizoid state more apparent, because it flagrantly contradicts the more tenaciously clutched belief that *the planet is static*.

Note that Rotonians have no objection to the *word*: "gravity," pertaining to the *process* whereby Earth flattens their undersides. They just think it has nothing at all to do with rest and staticness. It has nothing to do with a force of attraction. It has everything to do with absolute motion, as indicated by their accelerometers.

Privately, Rotonians feel sorry for the poor confused Earthians. They are, however, as compassionate as they are diligent scientists. So the Rotonians openly admit that they are not 100% sure their initial conception of gravity is more valid than the Earthians'. They resolve to humor and respect their Earthian hosts—superstitious as they may be—and to openly discuss their disagreements. Most importantly, Rotonians decide to do a thorough investigation, to study humans, their customs, their weird static theories, and especially the data and physical phenomena that have been used by Earthians to create this oddly distorted picture of reality.

As these first impressions settle into a more comprehensive assessment of human psychology, sociology, and Earthian physics, Rotonians are especially eager to devise an empirical test that would settle the matter. They would then either have to eat crow and admit the Earthians had had it right, or they *and the Earthians* would discover, among other things, that the direction of gravity is not downward, but *upward* (as indicated by accelerometer readings) and take it from there.

To clarify the situation, note that Rotonians have discovered only two things that cause non-zero accelerometer readings:

1. Rotation or
2. Propulsion (as by muscles, magnets, piston engines, rockets, etc).

The Earthians' have now insisted that a third thing should be added to the list:

3. A state of "*rest*"—as found on a large body of matter.

Rotonians object to this new category for its irrationality: *rest* and *acceleration* are contradictory concepts. They refuse to participate in the schizoid Earthians' confusion over accelerometer readings. Buying into the Earthian delusion of staticness would mean yielding to the "pomp of superfluous causes." Instead, Rotonians guess that their list remains essentially correct. They only need to add one more—admittedly huge—source of propulsion. The second item on their list needs modification by adding the simplest state of matter:

Without* muscles, magnets, piston engines or rockets, *brute matter all by itself acts as an inexhaustible source of perpetual propulsion.

It is immediately evident that the latter possibility entails profound changes to their own long-held views of matter, motion and the Universe. Happily, arrival of the friendly Rotonians has rekindled in Earthians a sense of wonder and scientific curiosity that, in many quarters, had seemed to be lost. So the two civilizations are now working as a team to answer the questions raised by Rotonians, by diligent scientific research. In the Earthian literature on gravity Rotonians find several points that invite deeper investigation—some of which echo their own research back home. The first and most important point is, however, unique and new to them, but curiously not new to the Earthians. It's the means by which the contrasting perspectives can be *tested*, to see unequivocally which one should prevail.

Rotonians had already wondered what would have happened if, instead of having to "land" on Earth's surface, a hole had been dug through the planet (and evacuated) so as to allow falling all the way to the center. Now they find that this idea had occurred to Earthians even earlier than 1632, when it was proposed as a serious thought experiment by the celebrated *father of modern science*, Galileo Galilei. Initially, Rotonians are shocked that Earthians had not thought to carry out this experiment long ago. As they acquired a deeper understanding of human culture, however, the shock turned to dismay. Galileo's experiment could remain neglected because of the depth of Earthians' belief that matter is composed of static, fragmentary chunks of stuff. It's as though this belief is *not* to be tested; it is to be taken for granted—virtually, if unconsciously, worshipped—as obvious as the beliefs that gravity is some kind of attractive force and that the law of conservation of energy is inviolate. As long as these beliefs remain firmly held as "knowledge," as long as scientific curiosity is squelched by Earthians' propensity to cling to authority, they would see no reason to actually carry out Galileo's experiment.

So much for history. Presently, the Rotonians' arrival seems to have inspired a kind of *renaissance*. Scientists from both perspectives have joined forces to build and operate the Earthians' *and the Rotonians* very first Small Low-Energy Non-Collider.

6. From Einsteinian Gravity to the Space Generation Model

> *There are no sacred cows in physics. Laws of physics such as conservation of energy, or whatever, are made to be tested. —*
>
> Sheldon Lee Glashow : Nobel Laureate [20]

As preparations get underway to perform the crucial experiment, Rotonians delve deeper into Einstein's celebrated theory of gravity (GR). In the course of their investigation, they find not only several echoes of their own early research, but the means by which to build a whole new gravity model. Rotonians are thrilled to see their model's potential to *explain why* GR seems to work as well as it does. Furthermore, the new model provides predictions—as we should require—that appear to accord just as well as, if not better than, GR with confirmed empirical evidence. Rotonians call this new scheme the Space Generation Model (SGM). The most extreme difference between GR and the SGM is in their respective *interior solutions*. While the empirical test of the interior solution (Small Low-Energy Non-Collider) is still in preparation, it is worthwhile to see how the Rotonians build up the SGM, to study how it differs from GR in domains other than the interior, and its consequences for cosmology.

One of the facts Rotonians see as pivotal in their new conception of gravity is that, while motion-sensing devices indicate that large bodies of matter are moving outwardly with a wide range of accelerations and velocities, they are nevertheless stable and persistently coherent. They maintain their proportions so as to produce the *visual impression* of staticness, even as they exhibit *tactile evidence* of non-uniform, outward motion. Rotonians grasp that reconciling the visual impressions with the tactile evidence requires the existence of a *fourth spatial dimension*.

From basic geometry, they argue as follows. When the space of a given number of dimensions exhibits evidence of non-Euclidean *curvature*, a new spatial dimension is logically implied. Rotonians build on an analogy sometimes discussed in the literature to support this argument. Before expounding on this inter-dimensional analogy, however, let us more fully set the context by recalling the Rotonians' reconciliation of the *null* result of Michelson's interferometer experiment with the *positive* result of Sagnac-like experiments.

The Rotonians' explanation is consistent with the common relativistic explanation that the arm of the interferometer parallel to the direction of motion Lorentz contracts by $\sqrt{1 - v^2/c^2}$ so that the perpendicular light beams return at the same time, yielding a null result. Since clocks on Roton's rim are slowed by this same factor, Rotonians agree with Einstein that this combination of facts argues for describing the spacetime geometry of Roton's plane of rotation (e.g., within one of Roton's spokes) as non-Euclidean. The rates of clocks and the lengths of tangentially oriented rods within the spokes vary with distance from the rotation axis. Stationary tangential *speed* is the cause.

The logic of Einstein's rotation analogy hinges on the fact that the *squares* of the velocities in the case of rotation are analogous to the so-called *gravitational potential*

$\Phi = -GM/r$ whose dimensions are also velocity squared. When divided by c^2, the squared velocities and potentials both yield quantities corresponding to the magnitude of curvature. In the case of rotation the pertinent speed is $r\omega$, i.e., the speed of the rim or any part of Roton closer to the axis. In the case of gravity the pertinent speed is $\sqrt{2\Phi} = \sqrt{2GM/r}$ i.e., the speed that an object falling from infinity would appear to have at any closer finite distance r. Rotonians reject the Newtonian-Einsteinian idea that potential corresponds to a *negative* velocity that *could* happen. They instead regard it as a *positive* velocity that is *real and happening all the time.*

The physical situation and essence of Einstein's rotation analogy is captured in Figure 7, where a radial expanse of Roton—from axis to rim—is shown alongside a radial expanse of a large gravitating body, from the surface to a very large distance beyond. The color spectrum indicates relative clock rates, where red represents a lower frequency and blue a higher frequency. And accelerometers indicate maximum magnitudes at the rim (Roton) and the outer surface (planet).

Both of these systems are *stationary*. Well known relativists of the 20th century: Landau and Lifschitz, [21] Christian Möller, [22] and Wolfgang Rindler, [23] all referred to uniformly rotating systems as being *stationary*, as distinct from *static*. Stationary motion indicates a system whose overall location and proportions remain constant, as it moves in place. Whereas a *static* system is one that does not move at all.

The motion-induced pattern of clock and rod relationships found on Roton exhibits a stark *discontinuity* with the surrounding space, which does not rotate.* One of the key distinctions at the heart of the SGM is the difference between motion *through* space, as compared with motion *OF* space. Linear speed and linear acceleration (e.g., produced by rockets) as well as rotational motion are examples of *motion through space*. Uniform rotation through space is a special case because—unlike linear motion—it is *stationary*. Though seemingly obvious, the specification, *through space* is made explicit for the purpose of contrast with the analogous case of a gravitating body.

Note that the rotating body exhibits a *range of accelerations* that nevertheless leave the approximately rigid members of the system intact. A similar circumstance is found on and around a gravitating body. Imagining that the single tower on the right side Figure 7 is multiplied by many towers at different angles, we come to envision not stationary motion through space, but *stationary motion OF space*—in every radial direction. Motion-sensing devices (accelerometers and clocks) indicate that volumetric space is being *generated* by matter (hence the name of the model, SGM). We have different accelerations at different radial distances, and the structure does not disintegrate because the motion is taking place in four, not three, spatial dimensions.

Invoking an extra spatial dimension is not, as some readers might initially suspect, an *ad hoc* fix to an implausible proposition. Extra dimensions have often played a role in theoretical physics—from some of Einstein's early musings to modern string theory. In these other cases invocation of extra dimensions often does have the character of an

*This is at least true in the Newtonian limit, which neglects the possibility of extremely tiny effects like *frame-dragging*.

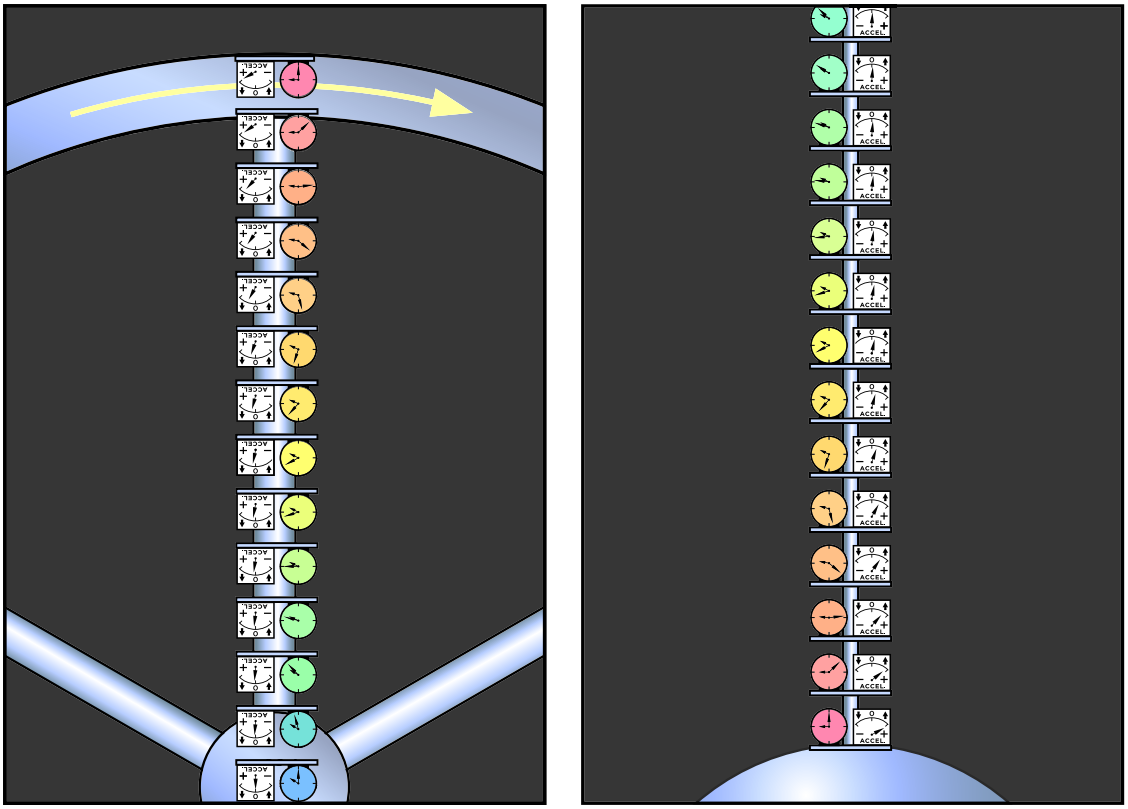


Figure 7: **Arrays of Motion-Sensing Devices** — **Left:** inward and tangential (rotation). **Right:** outward and radial (gravitation). The range of constant non-zero accelerometer readings combined with the range of constant clock rates indicates that both of these systems—rotational and gravitational—are undergoing *stationary motion*. Stationary motion of the rotating system is motion *through* space. Whereas stationary motion of the gravitating system is evidently *motion OF space*. Spacetime *curvature* caused by this motion implies a *fourth spatial dimension*.

ad hoc, or unphysical purpose, but not in the present case. Independent of physical ideas, extra dimensions, especially a *fourth* spatial dimension, are common themes in the entertainment industry as well as the mathematical literature. This prior work is dense with flimsy or irrelevant arguments and dubious conclusions. Meanwhile, an exceptionally simple and coherent way of conceiving a fourth spatial dimension, and relating it to our gravitational experience, has been possible—and even testable—as the Rotonians will now show.

7. Fourth Spatial Dimension by Analogy and Experience

> *If a fourth-dimensional creature existed it could, in our three-dimensional universe, appear and dematerialze at will, change shape remarkably, pluck us out of locked rooms and make us appear from nowhere. It could also turn us inside out. —*
>
> Carl Sagan, 1980 [24]

7.1 Fun and Illuminating Analogies

Frolicking with imaginary worlds of higher and lower dimensions than our seemingly $(3+1)$-dimensional existence has been a recurring theme of mathematicians, entertainers, and physicists for over 135 years. The parenthetical notation $(n+1)$ is common in the literature, where the n refers to the number of spatial dimensions and $+1$ refers to *time*. We will also sometimes use 2D, 3D, 4D, to refer to a respectively dimensioned "world," where time is implicitly included, for example, in the 3D world ("three-dimensional universe," as Sagan calls it) that we Earthians are often imagined to inhabit.

Though many presentations about dimensionality across the range of communication media are intended for fun only, Sagan's statement above is presented in the context of a serious treatment of scientific matters. To the Rotonians, it is *utter nonsense*. Centuries ago Rotonians came to the actually rather obvious conclusion that physical dimensions—including those of space—are a *package deal*. Points, lines or planes can exist as mathematical *abstractions*, but not as isolatable physical things.

Rotonians argue that even the *physical* dimensions of matter, time and space as a whole are not isolatable elements of reality, but are similarly *interdependent*. Any "one" of them exists only because they all exist; any "one" of them implies all the others. At the "lower" end of the hierarchy of spatial dimensions, the dependence on higher dimensions is more obvious: It's not hard to see that a *point* is not physical, but only represents a location on a line. A *line* is merely an abstract trace on a surface. A *surface* may seem more tangibly real. But on closer inspection we discover that a surface is ultimately just a fuzzy zone where a material array of one state or density lies adjacent to an array of a different state or density. The adjoining "surface" is not a real physical thing. It's an abstraction.

Which brings us to the question: Is a *volume* of space also only an abstraction? To which Rotonians would answer: A three-dimensional volume is surely less abstract than a point, line or surface. Yet it is ultimately inseparable from matter and time. The latter dependencies will be clarified later. Suffice it for now to say that our capacity to conceive of the "lower dimensional" entities point, line, and surface and even volume depends on our existence as material, volumetric (and temporal) bodies. *All* of the dimensions appear necessary to facilitate abstracting any one of them from the others, for the purpose of mathematical and sometimes even physical exploration. So a volume conceived *by itself* is as abstract as a surface. It becomes physical only by virtue of the matter that fills and surrounds it, and the associated pattern of motion of the whole edgeless arena in which it is found.

One of the most useful mental tools for understanding the relationship between dimensions is that of *analogy*. Sagan's remark above is based on an analogy whose origins may be traced back to Edwin Abbott's classic 1884 story, *Flatland*. [25] In *Flatland* we encounter imaginary sentient beings of only *two* spatial dimensions who are "looked down upon" by imaginary sentient beings of *three* spatial dimensions. The 3D creatures have the power to "pluck" the 2D Flatlanders from their surface, to flip them over and put them back on the surface—perhaps in some new and otherwise inaccessible location. Sagan simply extends the situation up a dimension, so that *we* are the lowly 3D creatures who are at the mercy of higher 4D creatures.

The magical act of "plucking" is essentially the same in both worlds. It assumes a *disconnect* between dimensional states that is not at all physical. Note that, in reference to Sagan's remark, the analog for a 2D creature having its shape changed or being flipped over is a 3D creature being "turned inside out" or "appearing from nowhere." A mathematician or entertainer is clearly at liberty to make up such a story. But a physicist should be loath to take it seriously. You cannot "flip over" a piece of a surface because the surface does not exist as a physical thing, and because a surface cannot be *separated* from the 3D continuum in which it resides. So too for a step up the dimensional hierarchy.

If any living creature really resided *on a surface* this would clearly only be possible if it also had some extension into the third as well as the first two dimensions, by virtue of its being actually (as we can plainly see) continuous with and ultimately of the same dimension as the higher volumetric space. For analogous reasons, 3D creatures cannot be plucked out of volumetric space, manipulated in "hyperspace" and put back in their lowly world with their insides now on the outside. No "4D creature" can separate a "3D creature" from her world because they are both ultimately of the *same* world, with the *same* dimensionality. To deny this is physically ridiculous. It's like attaching physical reality to the fantastic superpower things depicted in a cartoon. As though the possibility of thinking it and drawing it makes it real.

If hyperdimensional space exists, then seemingly 3D creatures are actually of that hyperdimensionality too. This argument thus also bears against the absurd proposition found in string theory and other (beyond or not even) fringe science that physical dimensions can be "compactified" to some particular tiny size. It's just more cartoonish nonsense. Physical dimensions are inseparable, "one" from the "others." So however many dimensions there are in the world, all subcomponents of the world are also of that dimension. Thus, *dimensions don't have sizes*. They are all ultimately continuous with one another, quite sizelessly so. Isn't this obvious? Though perhaps not to the theatrical ones among us, it seems to have been obvious to the philosopher P. D. Ouspensky, who succinctly and wryly captured the idea:

> We must find the fourth dimension, if it exists, in a purely experimental way . . . If the fourth dimension exists, one of two things is possible. Either we ourselves possess the fourth dimension, i.e., are beings of four dimensions, or we possess only three dimensions and in that case do not exist at all. [26]

Ouspensky's comment is clearly applicable no matter what the dimensional number: "If the 29th dimension exists, one of two things is possible. Either we ourselves possess the 29th dimension, i.e., are beings of 29 dimensions, or we possess only 28 (or fewer) dimensions and in that case do not exist at all." To reiterate, whether our concern is the seemingly separable spatial dimensions (first, second, third, ...) or the physical dimensions of matter and time, Rotonians think it is imperative to realize that none can exist without all the others. This is the most logical working hypothesis, in any case.

Rotonians hold this view because they understand that mathematics is not physics. However useful or enlightening it may sometimes be to mentally separate one dimension from the others, this act is always a mere unphysical abstraction. The set of mathematical or graphical possibilities is much bigger than the set of physical possibilities, because the only constraint in art and fantasy is imagination, which is boundless. Whereas the real world is constrained by physical limits and interdependencies. Being a physicist means trying to understand those limits and interdependencies, not inventing new limits or ignoring demonstrable interdependencies, for the hell of it, for the *entertainment value* of doing so.

It is of the utmost importance to perceive where mathematics ends and physical reality begins. "*Relative* acceleration" says nothing about whose undersides are flattened. Spacetime curvature will remain a half-baked enigma until we grasp what matter *does* to cause it. Contrary to popular belief, gravity most certainly is *NOT* geometry. The idea that dimensions are separable from one another Rotonians see as one of the many pernicious symptoms of Earthians' static, fragmentary view of the world.

7.2 Significance of Curvature

With this background into physical and spatial dimensions, we are better equipped to consider its bearing on non-Euclidean geometry. Note that these mathematical subjects emerged on Earth at about the same time, but are often discussed independent of each other. Though the number of spatial dimensions is routinely specified in discussions of non-Euclidean geometry, the relationships between spatial dimensions need not have anything to do with non-Euclidean geometry. "Flat" Euclidean laws may be fully obeyed even in hyper-dimensional spaces. But now we are talking about *gravity*, and its physical implications, consequences, and manifestations. So in this case the connection between dimensions and curvature may be very tight indeed, as the Rotonians think it is.

Uniform motion of a point along a $(1+1)$-dimensional straight line would yield a zero accelerometer reading—supposing, of course, that we allow the "extra" dimensions of mass and volume required for such a thing. If the background space (beyond the line) is Euclidean, then if the line should begin to *curve*—looking "down" on the scenario from a higher dimensional perspective—we suddenly require one more dimension of space, and we find non-zero accelerometer readings to reflect the change in direction. If the curved line is contained in a flat plane, then as soon as the line straightens out, the accelerometer reading would again become zero.

Now if the whole $(2+1)$-dimensional plane should curve into a new direction, we suddenly require a third dimension of space and we'd find anything moving around the axis of curvature to yield a non-zero accelerometer reading. If we—from our higher-dimensional perspective—see the curvature turn the surface into a *cylinder*, we would say the plane was actually only *bent* (not *curved*) because Euclidean laws of a flat surface still apply on a cylinder. Suppose, on the other hand, that the plane surface contorts into the surface of a *sphere*. In this case the laws of Euclidean plane geometry do not work. For example, the angles of a triangle drawn on the sphere do not add up to 180°.

In the spirit of stories like *Flatland* or *Sphereland* [27] let's imagine a civilization of sentient beings residing on the sphere. Let's call them Twoworlders. Suppose the sphere is enormously bigger than the Twoworlders and their cities, and that their speed of travel over the surface is extremely slow. For a long time they had thought their world was a flat Euclidean plane. The inkling, and ultimate discovery that they live on a 3D *sphere* builds up only slowly. It began as ever-widening survey parties came back with anomalous measurements that seemed to violate their Euclidean expectations. As they improved their surveying instruments and ventured further out, the Twoworlders eventually confirmed not only that Euclidean geometry fails, but the most logical explanation as to *why* it fails is because their seemingly 2D world is actually embedded in a world of at least one more spatial dimension.

Initially, the society of Twoworld included only a small, but growing faction of thinkers who regarded this evidence of non-Euclidean geometry as indicating the existence of a previously unrecognized spatial dimension—extending *above* and *below* their surface. These pioneers are sufficiently sophisticated mathematically to imagine our *higher* (so-called, *extrinsic*) perspective, looking *down* on the Twoworlders. Thereby, they conceive the possibility of a larger *volumetric* space in which their *surface* world is embedded.

Unfortunately, these hyperdimensional thinkers are up against a much larger group of entrenched dogmatists who insist that their world is $(2+1)$-dimensional, even if they need to adjust their account (akin to epicycles) to accommodate the new un-flat data. From their side, the dogmatists point out that the evidence for more than two spatial dimensions is *only inferred and deduced*, and that it remains true that *only two coordinates are needed to locate and identify every point on their sphere*. They argue that navigating their world does not *require* an extra dimension, so they resist invoking one. These arguments amount to what is known as the *intrinsic* perspective. The main feature of the intrinsic perspective is the fact just mentioned, that any point on the surface has an *address* of only two coordinates. There is no direct access to any place *above* or *below* the surface.

Even these Twoworldian-establishment sticks-in-the-mud see the error of their ways, however, when the explorers finally succeed in *circumnavigating* spherical Twoworld. A straight line returns to its starting point. How else to explain this than by positing the existence of another spatial dimension *around* which the travelers *moved* to make their discovery?

From our extrinsic, seemingly $(3+1)$-dimensional perspective we easily account for the Twoworlders discovery by use of volumetric 3D Euclidean geometry. Empathizing

with the Twowordlers' lack of this direct observability, we duly salute their powers of deduction and persistence. We cheer for all of Twoworld as they open the door to begin perceiving ever more evidence of the existence of a dimension beyond the visually obvious two, to which they seemed to be confined.

In 1968, building on the work of physical-philosopher, Hans Reichenbach [28], Richard Swinburne [29] appealed to exactly this kind of analogy to assess *our* relationship to a possible fourth spatial dimension. The geometrical argument I've presented is thus not new, but its *connection to gravity* is. Establishment physicists claim that GR fully accounts for our gravitational experience, with its $(3+1)$-dimensional non-Euclidean geometry. After explaining the difference between the intrinsic and extrinsic perspective, for example, a modern textbook on GR by Hobson, Efstathiou and Lasenby states:

> Intrinsic geometry is all that remains with any meaning . . . When we talk of the curvature of spacetime in general relativity, we must resist any temptation to think of spacetime as embedded in any 'higher' space. Any such embedding, whether or not it is physically realised, would be irrelevant to our discussion. [30]

The alleged irrelevance of "higher space" to general relativists is due to their lack of interest in *gravity itself*. They care little to explore or explain the *physical process* that produces spacetime curvature. Relativists are primarily concerned with the *static geometry* of Einstein's theory: Mathematical problems, not physical reality. So they urge their readers to "resist the temptation" to think outside the tiny box of ancient dogma.

7.3 The Clinching Argument

> *Analogy is surely the dominant idea in the history of the concept of dimensions.* —
>
> Thomas Banchoff [31]

Coming back to our scenario of Twoworlders, it is especially noteworthy that the clinching piece of evidence—found convincing by the staunchest establishment geometers—involved traveling *all the way around* the surface of their world. Even as we admit the fanciful unreality of two dimensional sentient beings, we nevertheless see the heuristic value of the *analogy*, of empathizing with Twoworlders' experience in trying to conceive of a *third* spatial dimension. We see that this experience is at least potentially parallel to our own efforts to conceive of a physical *fourth* spatial dimension.

The connection becomes all the more evident, as we consider humanity's store of data supporting the idea that the geometry of the spacetime we reside in—due to the Earth's and the Sun's mass—is *curved*. $(3+1)$-dimensional *Euclidean* geometry is adaptable to most, if not all, confirmed predictions of *Newtonian* gravity. But $(3+1)$-dimensional *Reimannian* (*non*-Euclidean) geometry is a much more natural fit to *post*-Newtonian observations that are chalked up to spacetime curvature, as predicted by GR. Classic examples include light-bending around the Sun; the perihelion advance of Mercury's solar orbit; and the Shapiro time delay test.

To explain the curvature due to gravity by analogy with the Twoworlders' experience—as being due to the existence of a higher dimension—we come upon this pivotal question: Is there a path, in seemingly $(3+1)$-dimensional spacetime, of an undisturbed test object analogous to the path over and around Twoworld's surface that would similarly clinch the argument for Earthians. Note that the Twoworld path involves *motion* all the way *around* its (seemingly 2D) *surface*. Therefore, the analogous path in Earthians' case must be one of motion that goes all the way *through* the (seemingly 3D) *volume*. In other words, the analog of the Twoworldian's clinching argument representing their discovery of the *third* spatial dimension, is for Earthians to test the existence of a *fourth* spatial dimension by building and operating humanity's very first Small Low-Energy Non-Collider.

This line of thought therefore represents yet another compelling reason to at last carry out the experiment proposed by Galileo in 1632. This test would determine whether or not we live in a world of three or four spatial dimensions because if the test object oscillates in the hole through the center (as per Newton's and Einstein's theories) then the static $(3+1)$-dimensional, *intrinsically* curved picture would suffice to accommodate it. The staticness of gravitational fields would be confirmed, as gravity would be shown to cause falling accelerometers to accelerate without indicating any such motion on the device. Though it accelerates, its reading is zero. An oscillation result for Galileo's experiment would prove this bizarre prediction to be a fact: Accelerometers often lie and there'd be no need for a fourth spatial dimension.

On the other hand, if the falling test object does not pass the center, this would confirm the existence of a fourth spatial dimension because, first of all, it would prove the truthfulness of accelerometer readings. (See Figure 8.) It helps to visualize an omnidirectional array of accelerometers on towers over the surfaces of large massive bodies, as in Figure 7. Accelerometers tell us that what accelerates is the large gravitating *source* body and its surrounding space. Clocks (the accelerometers' partners) tell us that the body and its surrounding space have a maximum *speed*, that depends on its mass/radius ratio, and that this speed (as in the case of rotation) is the *cause* of the

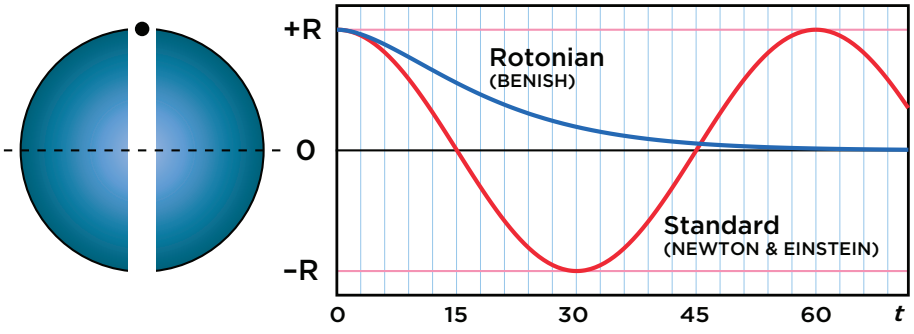


Figure 8: Comparison of Predictions. Newton's and Einstein's theories of gravity predict that the test object oscillates in the hole. For a sphere having the uniform density of lead, the period of oscillation would be about one hour. Based on their belief in accelerometer readings, Rotonians predict that nothing ever pulls the test object downward, so it never passes the center.

curvature. The very *essence* of mass is to create the space, the volume, whose actual $(4+1)$-dimensionality is revealed by the motion that *appeared* as that of a test object moving toward the center. Readings on a co-moving accelerometer and the fact of its *not passing* the center indicate that a more accurate assessment is to attribute the motion to the *source mass* and its co-moving space, as they propel themselves ever-outwardly past the falling test object.

This perpetual motion of matter and newly generated space is not to be conceived as motion *through* pre-existing static space, but as motion *OF* space: The motion of seemingly $(3+1)$-dimensional matter into or outfrom the fourth spatial dimension. This would be our most logical *inference*, our most logical *deduction*, just as the Twoworlders inferred and deduced the third spatial dimension from their analogous experiment. To reiterate, this result would establish the outpouring of space from matter as the *cause of the curvature*. This $(4+1)$-dimensional process is gravity. Everything moves, all the time.

7.4 Four-Dimensional Graphics?

A few remarks are in order about the limitations of our analogy. One of the many artificial aspects of the Twoworld scenario is that Twoworlders have no plausible means of locomotion. They have no reason to expect any non-zero accelerometer readings because they do not possess the spatial volume required to accommodate matter. Only by allowing all known dimensions—both physical and spatial—into the picture do we get the possibility of coherent material bodies and non-zero accelerometer readings.

One of the simplistic arguments sometimes raised against the idea of four spatial dimensions is that in our experience we can arrange only three mutually perpendicular axes. We cannot directly *see* the fourth spatial dimension as a fourth perpendicular axis. Neither could Twoworldians directly see the third axis. But from striking evidence of curvature, they deduced its existence.

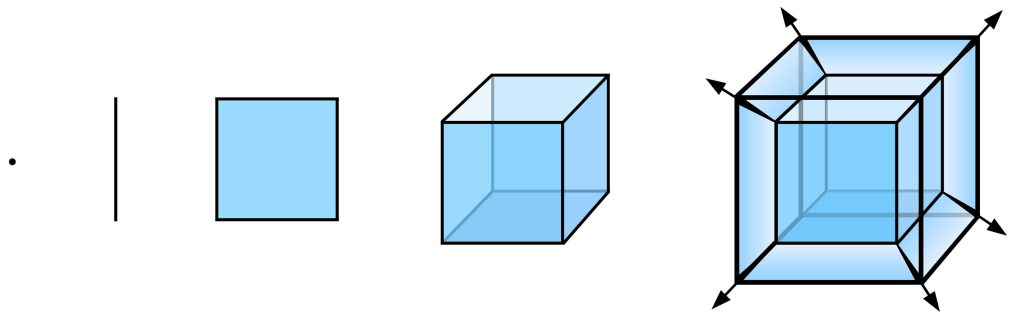


Figure 9: Building up dimensions. Starting with a zero-dimensional point, as soon as it moves, we get a one-dimensional line. When the line moves perpendicular to itself, we get a two-dimensional square. When the square moves perpendicular to itself, we get a three-dimensional cube. The last step suggests what happens when a the whole of a three-dimensional object moves perpendicular to itself: We get a four-dimensional hyper-volume, known as a tesseract. These pure-geometry-inspired images suggest a connection to gravity as a process of outward motion *OF space*.

Moving "up" the dimensional hierarchy brings greater complexity. In our world we have matter, volume, time, and non-zero accelerometer readings. We also have many attempts to graphically depict the fourth perpendicular. One of the most popular such depictions has been given the name, *tesseract*, or *hypercube*. We build our way up to a tesseract as in Figure 9. And Figure 10 is a collage of a few hypercubes found in books, magazines, and on the internet.

Such images are usually presented in discussions having only to do with geometry and

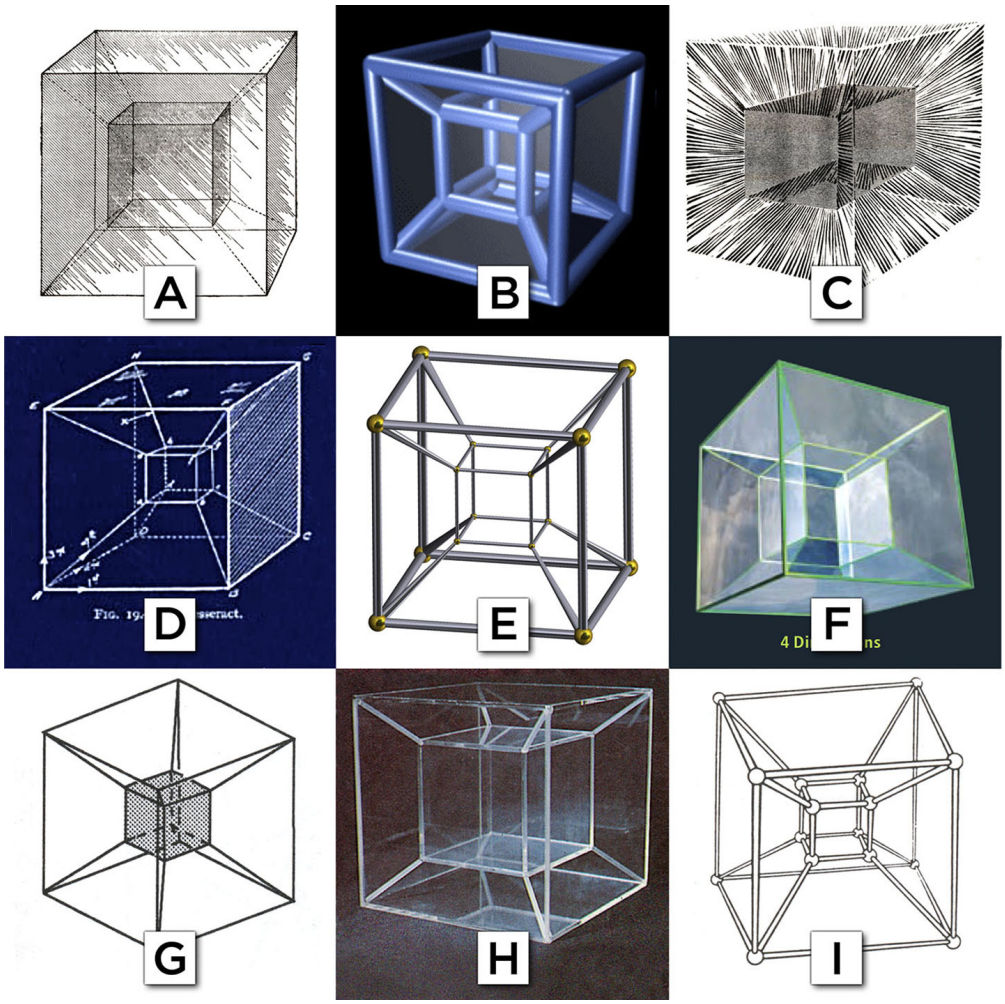


Figure 10: Hypercube (Tesseract) Gallery: A) Claude Bragdon; B) Wikipedia; C) Martin Gardner; D) Alexender Horne; E) Victor Schlegel; F) Jan Ambjørn, et al; G) Clifford Pickover; H) Carl Sagan; I) Rudy Rucker. The geometer Thomas Banchoff has described a tesseract as a "head-on view" or a "central projection" of a four-dimensional cube. Motivated entirely by geometrical, as opposed to physical considerations, these images are all supposed to represent an "extra" spatial dimension, which is just as static as the first three. I.e., there is no explicit, or even implicit relationship to matter, time, or gravity. Whereas in the Rotonians' Space Generation Model, the relationships are such that no space at all would exist were it not that matter is perpetually generating space by moving, with the unfolding of time, into (or outfrom) the fourth spatial dimension.

nothing to do with gravity. But they are clearly suggestive of our new model of gravity in which everything moves outwardly—perpendicular to all seemingly $(3+1)$-dimensional entities—in a $(4+1)$-dimensional way.

By merging their own research with the theories and observations of their Earthian hosts, Rotonians are pleased to have built up this qualitative understanding of the thing Earthians call gravity. Additional graphic representations of $(4+1)$-dimensional gravity will be presented in due course. But first Rotonians would emphasize the importance of a more rigorously analytical connection to Einstein's theory. The curvature they have now come to expect relates to certain physical parameters, constants, and equations that sometimes resemble, but sometimes profoundly differ from Einstein's relativity equations.

8. Always Finite Curvature

> *A singular region represents a breakdown of the postulated laws of nature . . . A theory that involves singularities and involves them unavoidably, moreover, carries within itself the seeds of its own destruction. —*
>
> Peter Bergmann : Assistant to Albert Einstein, 1980 [32]

8.1 Black Holes?

Recall the right side of Figure 7: A tall array of motion-sensing devices planted on a large gravitating body. Considering its empirical significance, one of the many questions left unanswered by GR is: *What exactly does matter DO to cause these clocks to tick slow?* The same applies to accelerometers. *What does matter DO to cause the flattening of our undersides?* The more encompassing question is: *What does matter DO to cause spacetime curvature?*

Where Einsteinians draw a blank or invoke mathematical magic, the Rotonians see the answer in the *left* side of Figure 7: Uniform rotation. It takes relatively little effort to set a body into rotation *through* space. Rotonians are intrigued to discover that with no human effort or outside influence at all, brute matter—all by itself—produces the same effects, effects that extend not just on a plane of rotation, but throughout volumetric space. *Matter moves*, as does the surrounding space.

The most extreme manifestation of motion caused by a massive body's gravity is the contrast between the *source body* itself and a *test object* that is dropped from very far away: from the "top" of one of our instrument towers, "just this side of infinity." (Note: Just now and in what follows we will use the word *infinity* to mean an extremely large finite distance.) In fact, the rates of the clocks on the towers are slowed down by exactly as much as they would be if they were themselves moving with respect to an object dropped from infinity at *escape speed*: $v_{\text{ESC}} = \sqrt{2GM/r}$.

The significance of this speed becomes evident by going back to compare with Roton's rotation speed. Since the clocks on Roton are slowed by

$$f = f_\circ \sqrt{1 - \frac{(r\omega)^2}{c^2}}\,, \tag{7}$$

where $f_\circ$ is the (maximum) clock frequency on the rotation axis, the analogous relation for the tower clocks might seem to be

$$f = f_\circ \sqrt{1 - \frac{2GM}{rc^2}}\,, \tag{8}$$

where $f_\circ$ is now equal to the rate of a clock at infinity.

Eq. 8 is the prediction of GR. Rotonians foresee a potential problem with it, however, because the quantity $2GM/rc^2$ could conceivably become equal to 1, which would indicate motion—specifically, the speed $v_{\text{ESC}} = \sqrt{2GM/r}$ —becoming equal to the speed of light and the corresponding stoppage of clocks, i.e., $f = 0$. Equally, if not more serious, is the corresponding effect on lengths, because the *reciprocal* factor now comes into play. If $dL_\circ$ is a radial length increment at infinity, then the corresponding increment on a vertically oriented rod on our towers would be (according to GR)

$$dL = \frac{dL_\circ}{\sqrt{1 - 2GM/rc^2}}\,. \tag{9}$$

When $2GM/rc^2 = 1$, the length ratio:

$$\frac{dL}{dL_\circ} = \frac{1}{\sqrt{1 - 2GM/rc^2}} = \frac{1}{0}\,, \tag{10}$$

becomes infinite. The theory—under this circumstance—seems to require dividing by zero, resulting in a dread singularity. An even more severe spacetime singularity corresponds to the *center* of the massive body, whose "horizon" is also known as the *Schwarzschild radius*: $r = 2GM/c^2$. This prediction of GR has often been regarded as an "ugly" blemish, where "literally all hell may break loose." [33, 34] It has probably also helped to boost Hollywood ticket sales, because it's the defining feature of a so-called *black hole*.

8.2 Light Speed Limit; Stationary Outward Velocity; Maximal Geodesics

Rather than delve into the morass of troubles caused by this prediction, Rotonians prefer the physically more plausible route by which it is avoided altogether. This approach presents itself as a consequence of a prediction that Rotonians had derived prior to any experience with gravity. Back on Roton, in the course of developing their space program and their theory of electromagnetism, which involves the limiting speed of light, Rotonians contemplated the consequence of an imaginary (but ideally possible) rocket ship that maintains constant acceleration for a very long time.

According to Newtonian theory, the speed would be boundless, as given by the simple equation $v = at$, where a is the constant acceleration and t is the time, as measured by an observer in the initial unaccelerated rest system. As the Rotonians had long known, the properties of space, matter and time are all limited by the fact that no material body can reach the speed of light. One of the equations derived by the Rotonians to express this limitation agrees with the corresponding equation derived from Einstein's Special Theory of Relativity:

$$v = \frac{at}{\sqrt{1 + (at)^2/c^2}} \ . \tag{11}$$

As time t gets very large, v approaches, but never reaches the speed c.

Confronted now by the need to account for the rates of clocks on and around a gravitating body, Rotonians expect that a similar limitation must apply to the gravity-induced motion of matter. Bear in mind that we've already attributed a *cause* to the slowing of the clocks on our towers: It's the stationary outward velocity of those towers with respect to objects dropped from infinity. The path of such an object is an *extreme case* of falling for two reasons: It has no angular component of motion (it is perfectly radial), and a co-moving accelerometer would maintain a zero reading for the whole time—even prior to its being "released" at infinity. Paths whereby co-moving accelerometers read zero are called *geodesics* in GR and in the Rotonians' SGM.

Of these free-falling spacetime paths, the one described above (radial from infinity) is particularly special because it had *never* experienced any acceleration and a co-moving clock had a maximum rate at the outset. Rotonians posit that this means this clock's rate never changes. It is never accelerated, so it retains the maximum rate it started with for its whole time of fall. Rotonians therefore give these special paths the name: *maximal geodesics*. The *family* of maximal geodesics—from all different directions—thereby serves as an idealized standard of rest. The visible motion between the maximal geodesics and the towers they fall alongside is entirely attributed to the towers and the massive body at their base, because it is the latter array of motion sensing devices that unfailingly indicates non-zero effects of motion, as though matter were an inexhaustible source of perpetual propulsion.

This manner of conceiving the gravitational field near a massive spherical body has been at least partly validated by making predictions that agree with two classic tests of GR: the Vessot-Levine experiment (aka Gravity Probe A) and the Shapiro time-delay test. [35]

To mathematically represent the limitation on the speed of gravitating matter, Rotonians propose adapting the expression derived from *constant linear acceleration* to the case of gravity: *stationary outward acceleration*. Specifically, they substitute into Eq 11 the speed $\sqrt{2GM/r}$ for the acceleration-derived speed at. This yields what the Rotonians call *stationary outward velocity*:

$$V_S = \frac{\sqrt{2GM/r}}{\sqrt{1+2GM/rc^2}} \ . \tag{12}$$

Instead of depending on *time* (as in Eq 11) velocity in Eq 12 depends on the M/r ratio. The motion is stationary.

8.3 Well-Behaved Coefficients of Curvature

Though this approach changes the meaning of what a gravitational field is, and how it accommodates the light speed limit, the *metric coefficients* implied thereby result in a pattern of spacetime curvature that nearly exactly agrees with the standard exterior Schwarzschild solution for all weak-field cases. Where the Schwarschild solution gives $(1-2GM/rc^2)^{-1}$ for the radial coordinate, the Rotonians' SGM gives $(1+2GM/rc^2)$. And where the Schwarzschild solution gives $(1-2GM/rc^2)$ for the temporal coordinate, the Rotonians' SGM gives $(1+2GM/rc^2)^{-1}$. The difference between these coefficients for most astrophysical purposes is extremely small. We can see the difference graphically in Figure 11. The curves of the coefficients are simply *shifted* with respect to each other along the r-coordinate. For large values of r the curves are nearly indistinguishable.

One of the noteworthy consequences of this model is that it leads to the prediction of a *maximum force* in Nature. The same maximum force is predicted—via a much more complicated analysis—by GR. In 2009 I submitted a paper describing this result to the *International Journal of Theoretical Physics*. *ITJP* is where a paper giving GR's prediction

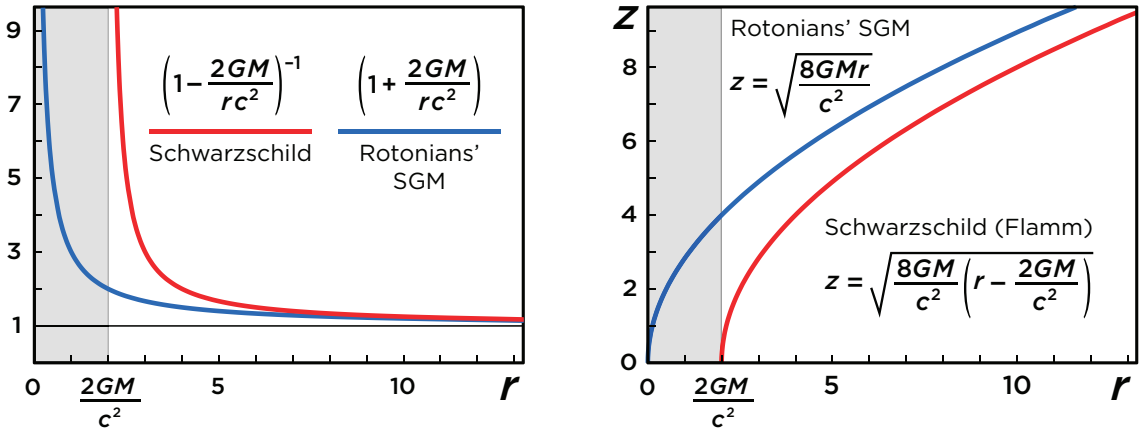


Figure 11: Space curvature coefficients. **Left:** The Schwarzschild coefficient unphysically skyrockets all the way to infinity (red) when $r = 2GM/c^2$. Whereas the corresponding coefficient in the Rotonians' SGM remains finite for any finite (positive) radius. There is nothing unphysical about it. **Right:** When GR's curve (red) is rotated around a vertical axis the result is the common funnel-shaped graphic (Flamm paraboloid) of an "all hell broken loose," sucking-monster *black hole* whose mouth is the size of its horizon. Whereas the Rotonians' SGM curve has no such mouth, no singular behavior, and no "ugly" predictions as found in GR. When r is large compared to $2GM/c^2$ (i.e, in weak field cases like the Earth and Sun) the curves in both graphs nearly coincide.

for the maximum force was published in 2005, so it is the appropriate forum for the new result. Though the journal's first referee recommended publication of my paper, and the author of the 2005 paper, Christoph Schiller [36] was also impressed, the journal's second referee rejected it. [37]

The important thing is that Rotonians have developed their model to the point of establishing agreement with confirmed empirical observations in "weak field" situations like those found around Earth and in the Solar System. We should *expect* this agreement, of course, if the model really does explain the existence of spacetime curvature as being caused by *stationary outward motion*. Rotonians argue that the model is coherent, logical, and needs most of all to be tested where even Newton's theory of gravity has not yet been tested.

9. Below the Surface, Newton's G, and (4 + 1)–D Spacetime

9.1 Stationary Outward Motion from the Inside Out

Let us now build on the analogy between uniform rotation and gravitation, and the $(4+1)$-dimensional implications of the observed effects. First, let's extend the maximal geodesics falling alongside our array of motion-sensing devices to the *center* of a spherical body. It is well known that, inside a uniformly dense sphere, the acceleration due to gravity is supposed to vary directly as the radial distance. Even if we had access to Earth's interior, it is not uniformly dense. Nevertheless, a variety of less direct laboratory experiments support the prediction—all of which the Rotonians agree with. The prediction is sometimes explained as being a consequence of *Gauss' Law*, or the *Shell Theorem*, whose validity traces back to the inverse square $(1/r^2)$ character of gravity.

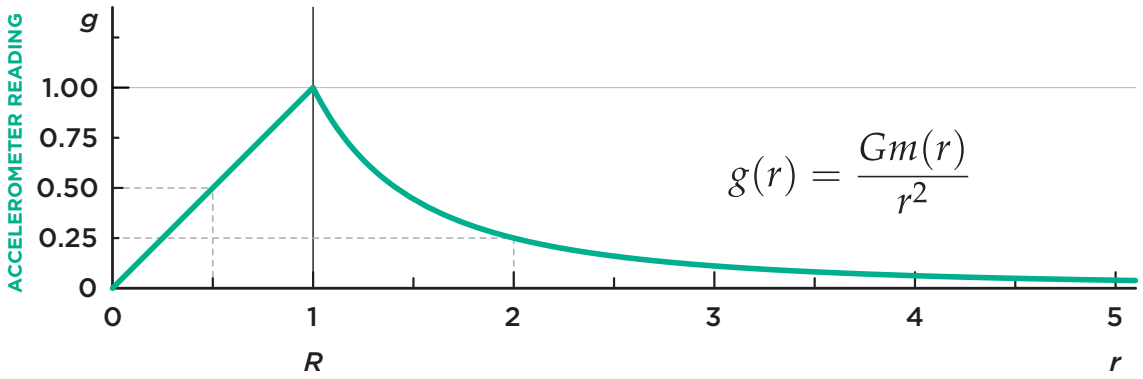


Figure 12: Acceleration due to gravity below the surface of a uniformly dense sphere increases in proportion to the distance from the center. At any distance, the matter contributing to the acceleration is only that within that distance. Outside the surface all the matter contributes to the acceleration, which falls off as the inverse square of the radius. One of the consequences of this law—indeed, the reason this *is* the law—is that the amount of space being generated *at all distances* beyond the surface is the same: $4\pi GM$. As distance increases, this distance-independent rate of *volumetric space generation corresponds to decreasing linear acceleration* because it is distributed over a surface area that *increases inversely* to the linear gravity law.

What it means is that the only contribution to the force (accelerometer reading) at some radial distance r between the center and the surface is caused entirely by the matter *within* r. In other words, the force produced by the matter beyond r increases accelerometer readings only beyond r, and is cancelled by symmetry within r. A graph of the acceleration with respect to radius below the surface is thus a straight line, as shown in Figure 12. The equation shown in the figure,

$$g(r) = \frac{Gm(r)}{r^2}, \tag{13}$$

means the acceleration is a *function* of r because below the surface the amount of mass m depends on the radius. For example, at $r = \frac{1}{2}R$ the mass is $\frac{1}{8}$ of the total. Doing the math, we get $\frac{1}{2}$ the acceleration of the surface at $\frac{1}{2}$ the distance from the center. Outside the surface ($r \geq R$) the same amount of mass is involved at every distance, so the acceleration decreases as the inverse-square of the distance.

If the *stationary outward velocity* below the surface is calculated on the same logical basis—as Rotonians think it should be—we get a similar linear relationship:

$$v(r) = \sqrt{\frac{2Gm(r)}{r}}. \tag{14}$$

At $\frac{1}{2}$ the distance from the center ($r = \frac{1}{2}R$) we get $\frac{1}{2}$ the surface velocity, and so on.

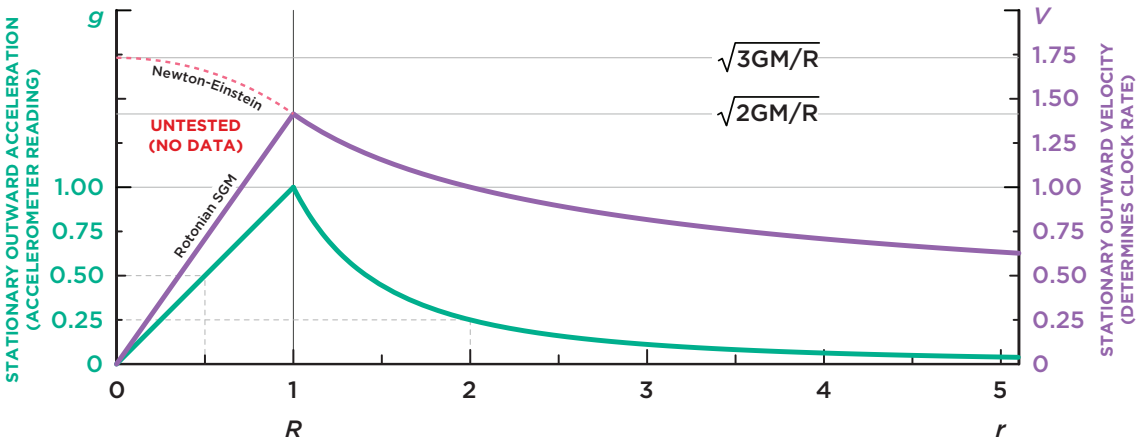


Figure 13: Stationary outward acceleration (green) and stationary outward velocity (purple)—both below and above the surface—of a uniformly dense sphere. Rotonians regard the graphs as indicating *outward* motion because that is the direction indicated by accelerometers. Newton's and Einstein's theories regard the massive body as *static*; they represent gravity as magically causing falling objects to move *downward*. Based on the latter conception, a body falling from infinity into a hole through the center would reach a maximum speed $\sqrt{3GM/R}$ (broken red line). Einstein therefore expects the rate of a clock resting at the center to be slowed *as though* it were moving with this speed. Whereas Rotonians see the body's center as analogous to a rotation axis, whose obvious lack of motion corresponds to clock rates being a *maximum*.

The findings of the above discussion are graphically combined in Figure 13, which shows the curves for both stationary outward acceleration and stationary outward velocity, both inside and outside a uniformly dense sphere. Conventional physics disagrees only with the Rotonians' extension of the velocity curve inside matter. Based on the assumed validity of the concepts of gravitational *attraction*, gravitational *potential*, and the *energy conservation law*, Newton's and Einstein's theories predict that the velocity curve within R continues upward from the surface to reach a maximum speed: $v = \sqrt{3GM/R}$ at the center, as shown in the Figure. Inside R is exactly where these assumptions have *never been tested*. The need to carry out Galileo's Small Low-Energy Non-Collider experiment thus raises its pretty little head yet again.

9.2 Motion Through Space vs. Motion *OF* Space

It is easy to see that the linear propulsion of a rocket ship *through* pre-existing space causes effects of motion such as flattened undersides and slow clocks. Everything in contact with the rocket engine is affected pretty much equally. From their experience on Roton, Rotonians perceive the greater complexity of motion due to rotation, where distance from the axis affects the magnitude of both acceleration and speed. Different locations are affected differently. Rotation involves a *range* of speeds and a *range* of accelerations that are both *stationary* and *through* space.

Rotonians bring this experience to bear on their brand new problem of understanding gravitational motion. They *instinctively* regard the positive readings of motion-sensing devices attached to the material structure causing the motion to mean that that material structure is itself moving—albeit in a more complicated way than they've seen before. The motion appears, by analogy, to be *stationary*, but not as motion *through* pre-existing space. Rotonians conceive the process, rather, as the perpetually outward *motion OF space*, which takes place simultaneously with perpetual self-regeneration of the material source body. A reasonable guess—to be discussed in more detail later—is that the matter/space ratio remains constant, as they both increase in the same proportion over cosmic time.

9.3 Positive Constant *G*: Into (or Outfrom) a New Spatial Dimension

The idea of space generation receives support from research conducted by Earthians in preceding centuries, especially by Isaac Newton, whose theory of gravity involves a universal constant named in his honor: Newton's constant, G. When broken down into the physical dimensions of distance (L), mass (M) and time (T), the dimensions of G come out as:

$$G \rightarrow \frac{L^3}{MT^2} \ . \tag{15}$$

Verbally, this can be expressed as *acceleration of volume per mass*. In both Newton's and Einstein's theories the meaning of G is made especially clear in the context of cosmology.

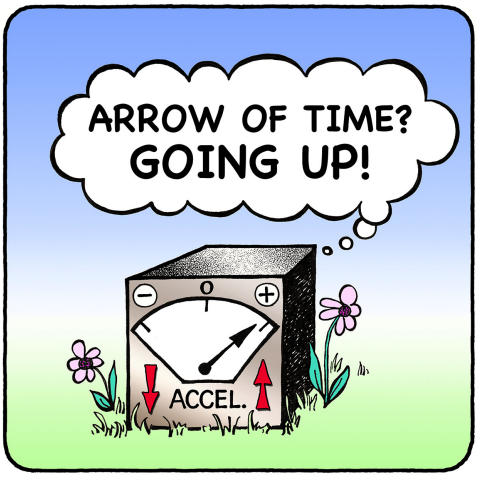


Figure 14: Temporal thoughts of an anthropomorphized accelerometer. A thinking accelerometer deduces that Newton's constant represents a *POSITIVE acceleration of volume per mass*. It thereby discerns that it is not just *time* and gravity that are *going up*. Being made of matter and occupying space, and knowing that others like itself indicate positive values in all directions around every body of matter, our reliably truthful motion-sensing device concludes: *Time only increases because space and matter also only increase.*

As the standard theory goes, space in the Universe (all of which was supposedly produced by the *Big Bang*) will either continue increasing forever (augmented by *dark energy*?) or it will—if the average cosmic density were sufficiently great—be sucked back out of existence by gravity. Whether thought of as *elimination of space* or attraction between material bodies, standard theories treat Newton's G as a *negative* quantity: subtraction of space or reduction of distances between bodies.

Conceived this way, cosmic gravity must be the cumulative effect of all matter in the Universe. Therefore, the process must be continually taking place *even locally*. Consistent with the fragmentary world view (mess?) that is standard physics, space is sucked "away" by the *static, unchanging chunks of stuff* that remain. The *attraction of gravity* means that matter is in a perpetual state of eliminating space from the Universe. Sadly, it's not politically correct to ask: *what exactly happens to the disappeared space?* The absence of a physically reasonable answer is another indication that *attraction of gravity* is a suspiciously flimsy idea. If it's true, and if cosmic density is sufficiently great, all space will ultimately disappear, which event is often called a cosmic *big crunch*.

We will return to the cosmological implications in the next section. For now it suffices to point out that Rotonians' interpret G not as a negative quantity, but as a positive *acceleration of volume per mass*. Space is never subtracted, but is perpetually added (multiplied) by gravity. To Rotonians this seems obvious, as indicated by accelerometers placed on source masses and as arrayed on towers such as in Figure 7. In a more playful spirit, Figure 14 adopts an accelerometer's-eye view of the matter.

9.4 Hovering Rockets and a Tubular Model of (4 + 1)–Dimensional Motion

Suppose the lone tower in Figure 7 is accompanied by an *array* of towers extending upward at various angles. The result (Figure 15) is further livened up by adding an array of "hovering" rockets interspersed between the towers. An inexhaustible supply of energy (fuel) would be required for the rockets to remain in formation. Rotonians interpret this fact as indicating the perpetual increase of energy generated by brute matter. They see the "hovering" rockets as *tracers* of outward motion that is always taking place, whether the rockets are there or not.

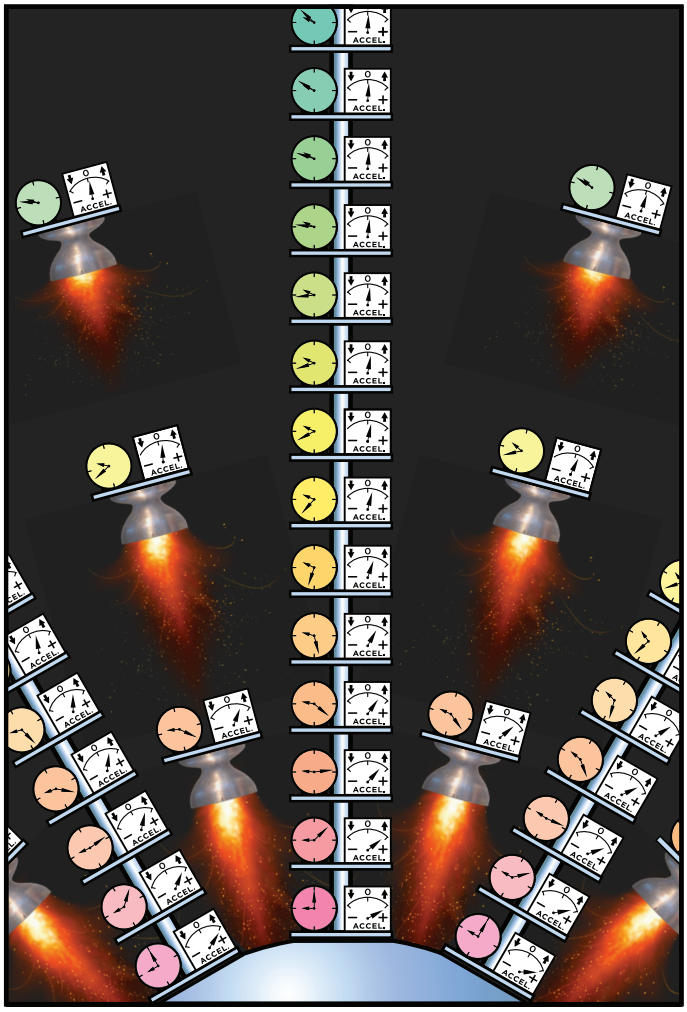


Figure 15: "Hovering" rockets in stationary configuration. The right side of Figure 7 is livened up by adding motion-sensing devices that are supported, not by material connection to the source mass, but by rockets. Brute matter, all by itself, is a source of perpetual propulsion whose linear magnitude diminishes with distance. Space is being generated in accord with the inverse-square law. When the source mass is as big and dense as a planet, the amount of energy needed to keep abreast of the outflow is enormous.

Accepting the truthfulness of accelerometers means that gravity is much more complicated than a fleet of flaming rockets. Stable coherence of the array of towers requires a fourth spatial dimension because the acceleration is not *through* pre-existing space; it is *OF* space itself. The spacetime curvature caused by stationary outward motion requires one more dimension *to curve into*.

Another illustration (Figure 16) facilitates an intuitive grasp of this proposal. Gravity is most commonly associated with the phenomenon of *falling*. The bottom of Figure 16 was inspired by a static $(3+1)$-dimensional graphic invented by L. C. Epstein as an attempt to explain how spacetime curvature is the cause of falling. Epstein illustrated the falling

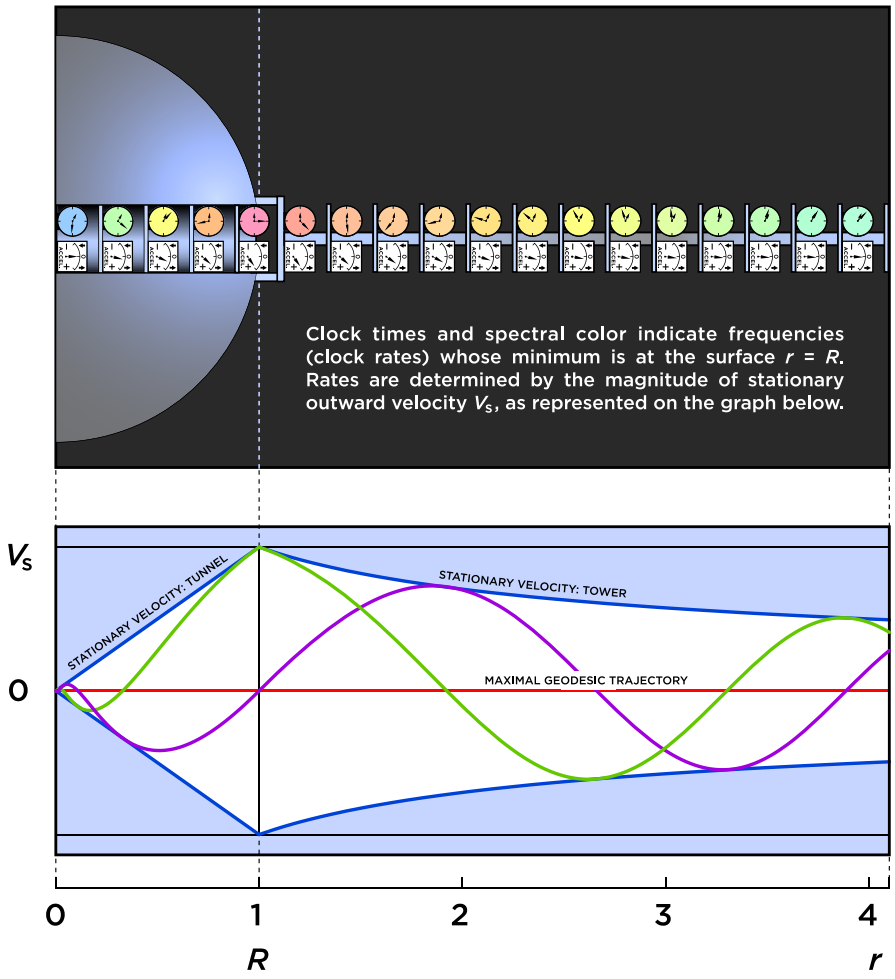


Figure 16: Tubular model of $(4+1)$-dimensional radial stationary motion. **Top:** Physical circumstance represented in the graph below; i.e., a gravitating body with a tunnel to its center and a tower attached to its surface. **Bottom:** V_S-axis represents stationary outward velocity; i.e., the stationary motion of space—into or outfrom a fourth spatial dimension. Think of the cross-sectional graph as rotating around the r-axis. Helices drawn on the tube at 45° to the axis facilitate visualizing the falling motion of maximal geodesics.

of bodies outside and inside a gravitating body by appeal to a bulged spacetime *tube*. [38] The profile of Epstein's tube is in fact similar to the velocity curve in Figure 13, including the dashed line of maximum velocity at the center. Suggestive as Epstein's tube may be, Rotonians object to its *staticness*. Acceleration and speed are shown to vary, depending on a falling object's initial speed and position on the bulge. But the tube itself is *STATIC*. Epstein evidently rotated the velocity graph once, regarded the resulting envelope as *unmoving*, and drew the paths of falling objects on the tube. That which mysteriously causes *other* things to move, does not itself move. The thing upon which motion-sensing devices register positive evidence of motion, is regarded as *STATIC*. How weird!

Rotonians think this makes no sense. So they invert the relationships by conceiving a tube that rotates with respect to the r-axis, through the plane of the page. *The things that reveal motion by motion-sensing devices that are attached to them are the things that move*. (Duh!) The rotating tube thus corresponds to the perpetually moving source mass. As in the case of ordinary rotation, the center (axis) is motionless, so there is no central bulge.

The closest thing to a *rest* system is the extreme case of an object, or *family* of objects, falling from infinity (maximal geodesics). By rotating the graph, Rotonians thus convey the idea of seemingly $(3+1)$-dimensional matter and space moving into a fourth spatial dimension. The situation is actually $(4+1)$-dimensional. Being stationary, the rotation accommodates the fact of seemingly rigid members of a planet and towers planted thereon, maintaining their structural integrity, even as they exhibit different speeds and accelerations.

Rotation on a plane or cylinder *through* space permits visually seeing the motion against a backdrop of the surroundings that do not rotate. But in the case of gravity, the motion is volumetrically omnidirectional. We are immersed in and are part of the motion, so its existence is not so directly or intuitively visible. Our imagined fleet of flaming rockets, with a range of magnitudes and directions that nevertheless *appears* not to move, is presented to help visualize what is physically going on.

Remember that Twoworlders also could not directly see their extension into the third dimension. By persistence and careful observation they nevertheless *deduce* it. They *infer* it from the less direct evidence of curvature—of moving in a previously unrecognized perpendicular direction—*around* their sphere into the third spatial dimension. The potential objection that the tube of Figure 16 indicates motion *perpendicular* to the actual direction of falling objects is answered by appeal to the analogous experience of Twoworlders. A dimensionally savvy Twoworlder explains to a dimensionally naive Twoworlder that "to every line there are *two* perpendiculars, not just one." Granted, the "second" perpendicular cannot be directly seen. But evidence of its existence may nevertheless be deduced by geometry and by exploratory motion *around* their surface.

Similarly, Rotonians grant that, for graphical communication purposes, the rotation of their tube is in a direction we *can* actually see. But it *represents* a direction we *cannot* so directly see. This new direction is to be *inferred* by the fact of motion indicated by accelerometers. It is to be *inferred* by the stationary tower that moves in the same direction past falling bodies that have never been accelerated. Based on their long experience

with absolute motion, the Rotonians have a strong hunch they've hit on the essence of gravity. They are pretty sure gravity is best conceived in accordance with this analogy, as motion-induced curvature into a fourth spatial dimension. Most importantly, they are extremely eager to settle the matter by letting Nature speak; to test the idea by building and operating Earth's very first Small Low-Energy Non-Collider.

9.5 Preview Into the Cosmic Significance of Newton's Constant *G*

In Figure 17 we see the rotating tubular graphs representing five different mass/radius ratios. According to the Rotonians' model, the *frequency*, and therefore rotation *period*, of every tubular graph representing any massive body in the Universe would be the same. This corresponds to a physical-mathematical *constant*. Different stationary motion patterns for different bodies are reflected by unique profiles of the vertical and horizontal axes (mass and density distributions). These correspond to the *variables*. Clearly the picture would become more complicated by trying to depict more than one body at a time. But even this should be possible, in principle. Beginning with simple cases provides a basis for building up a comprehensive picture of gravity, as its influence permeates everything: matter, space, and time—across the whole Universe.

Gravity must therefore affect and be related to the "other" forces that are commonly characterized as operating *separately* (each with its own exclusive *"quanta" of interaction*) on different scales or components of matter: nuclear, weak, and electromagnetic. The next section will more explicitly address how the SGM uncovers a clearcut relationship between Newton's constant *G* and the constants operating in these other physical domains, and the Universe at large. Presently, let's just keep that promise in mind as we round out the visual aid provided by our rotating tubes.

The surfaces of the bodies represented by the five different tubes in Figure 17 are at the same radial distance (*R*). Though equal in radial size, their graphs reflect a 16-fold range of *masses* and thus also *densities*. As noted in the caption, the purple and green curves are helices drawn on the tubes so that, as the tubes turn, the projected intersection of the helices onto the *r*-axis is always 45°. (Some readers will have seen spinning barber poles that give the illusion of a similar kind of axial motion.) This 45° constraint means that the rotation speed of the tube's envelope is everywhere equal to the speed at which any projected intersection of a helix appears to travel along the *r*-axis. For the appropriate rotation direction, this also means that the apparent projected speed is exactly that which an object falling radially from infinity would appear to have at any given *r*. The *r*-axis thus represents a *maximal geodesic* with effectively *zero* speed.

The visual *change in speed* of the helix-axis intersection (outside the surface, *R*) corresponds to the acceleration due to gravity *g*. Upon crossing the surface to the body's interior, the stationary outward velocity changes from *increasing* toward the center to *decreasing* to zero at the center. The *acceleration* of the projected intersection *below the surface* correspondingly appears to change sign and become *repulsive*. This velocity-dependent effect is not to be thought of as any kind of *force*, in the traditional sense. An object

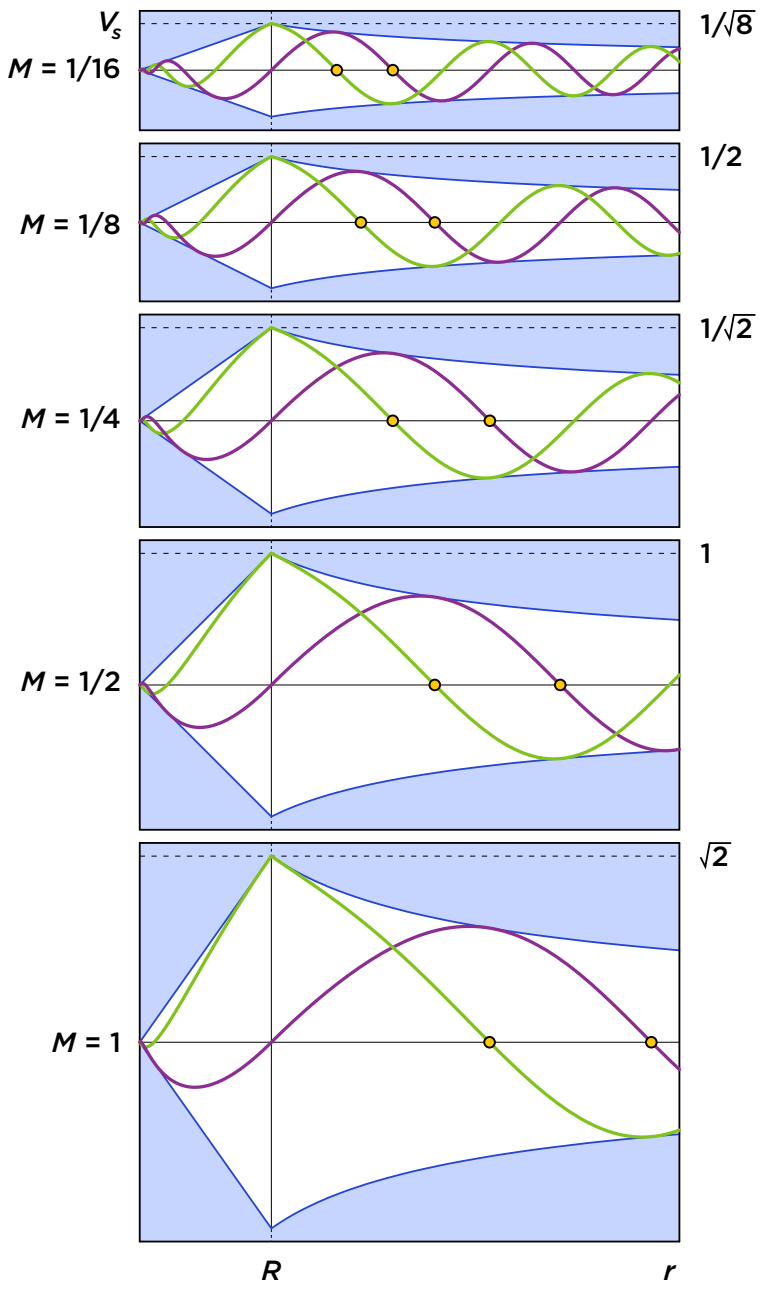


Figure 17: Tubular model of radial falling in $(4+1)$-dimensional spacetime. Flared white areas are to be thought of as cross-sections of tubes rotating with respect to the r-axis. Helices are drawn on the tubes (green, purple) such that their projected intersections with the axis (gold dots) are always at a 45° angle. This assures that the projected *speeds* of these intersections, as the tubes turn, always correspond to the speeds whose magnitudes are represented by height on the vertical axis; i.e., the tube's envelope. These speeds thus correspond to the towers (in Figures 7, 15, and 16) that move with respect to bodies freely falling from infinity ($V_S = \sqrt{2GM/r}$). Since all tubes—for all bodies of matter everywhere—have the same angular speed, the taller ones exhibit correspondingly greater apparent speeds—as also indicated by the correspondingly longer wavelengths. Although the graphs move perpendicular to the plane of the page, they *represent* radial, i.e., stationary *outward* motion—into or outfrom the fourth dimension of space.

released from the surface into a hole through the center, for example, would still initially *appear* to have a downward acceleration of magnitude $g = GM/r^2$.

Since this object will also never quite reach the center (according to the Space Generation Model) here too the motion eventually slows down, giving the *appearance* of a repulsion. This is an illusion created by the non-uniformity of the stationary outward velocity and stationary outward acceleration, both of which are empirically measurable with motion-sensing devices (accelerometers and clocks).

As emphasized above, one of the primary motivations for this graphic is to represent the $(4 + 1)$-dimensionality of gravitational stationary motion. If we try to depict this motion in the radial direction in preexisting $(3 + 1)$-dimensional spacetime, the thing flies apart. It is not at all stationary; it is impossible. But if spacetime is in fact $(4 + 1)$-dimensional, then we are justified to represent the motion as being *perpendicular* to the towers (Figures 7, 15, and 16); i.e., perpendicular to the plane of the page. Gravity may thus be conceived as a kind of "rotation" of $(3 + 1)$-dimensional spacetime into (or outfrom) a new dimension, the magnitude of which depends on the local distribution of mass. Motion-sensing devices give us reason to expect these geometrical consequences to be physically real. In a sense they are *more* real than our visual impressions.

Since the "tubular" rotation period of every massive body is everywhere the same, it must be related to the value of Newton's constant, G. A more comprehensive representation of the vast range of sizes and masses would show them scaled in terms of the velocity ratio V_S/c, which would be indicated by a horizontal asymptote (unreachable light-speed maximum).

With such scaling, the tube diameters of common gravitating bodies like stars and planets would be represented by small fractions of the light-speed maximum. Smallish M/r values (compared to c^2/G) correspond to many helical turns per radial (r-axis) distance interval, instead of the few turns, as shown here. The key idea is that this extent in stationary outward velocity space, this motion into a hyper-dimension, is the very essence of matter and gravity. An unturning tube collapses to a dead, abstract line. Without this state of perpetual outward motion, there would be no gravity, no matter, no space, no time, no life, no Universe.

10. Newton's Constant, Gravity, and the Universe

What is gravity?... What is inertia?... Is our much-exalted axiom of the constancy of mass an illusion based on the limited experience of our immediate surroundings?... How are we to prove that what we call matter is not an endless stream, constantly renewing itself and pushing forward the boundaries of our universe? —

Arthur Schuster, 1898 [39]

10.1 Rotonians' Crowning Upshot: Connecting *G* to Everything

The short answer to Schuster's 122 year old questions quoted above (especially, "How are we to prove . . . ?") is: *Build and operate humanity's very first Small Low-Energy Non-Collider*. Assuming the experiment proves that "matter *IS* an endless stream, constantly renewing itself and pushing forward the boundaries of our universe," the significance of the cosmic consequences would be difficult to exaggerate. In what follows the Rotonians uncover a cosmic pattern, a visual, mathematical and conceptual pattern that is as vast and encompassing as it is surprisingly *simple*.

The story culminates with the Cosmic Everything Chart in Figure 18. [40] To understand and fully appreciate the Chart, we will reach back to some of its raw ingredients: elements of the physical world as well as a variety of theoretical ideas from Earth's early 20th century quantum theory, cosmology and beyond. Prominently displayed near the Chart's middle, is the most potent nugget: A definition of Newton's constant *G* expressed in terms of measured quantities from the rest of physics. Rotonians perceive that, if this definition is proven true, it would be the veritable crown jewel of their research:

$$G = 8\left(\frac{\rho_\mu}{\rho_{\rm N}} \cdot \frac{c^2 {\rm a_O}}{m_{\rm e}}\right) , \tag{16}$$

where ρ_μ is the mass-equivalent density of the cosmic background radiation, $\rho_{\rm N}$ is the nuclear saturation density, $\mathrm{a_O}$ is the atomic Bohr radius, and $m_{\rm e}$ is the mass of an electron. Before telling the story from its beginning, note that, at least numerically, Eq 16 is nearly true regardless of its ultimate importance. The least well-measured constant is the nuclear saturation density ($2.85 \times 10^{17}\,\mathrm{kg/m^3} \pm \approx 6\%$). The best way to begin ascertaining whether or not the expression is more than a curious coincidence is to build and operate humanity's very first Small Low-Energy Non-Collider. If the test object does not oscillate, this would facilitate answering Schuster's questions and provide strong evidence that Eq 16 is both true and *extremely* important.

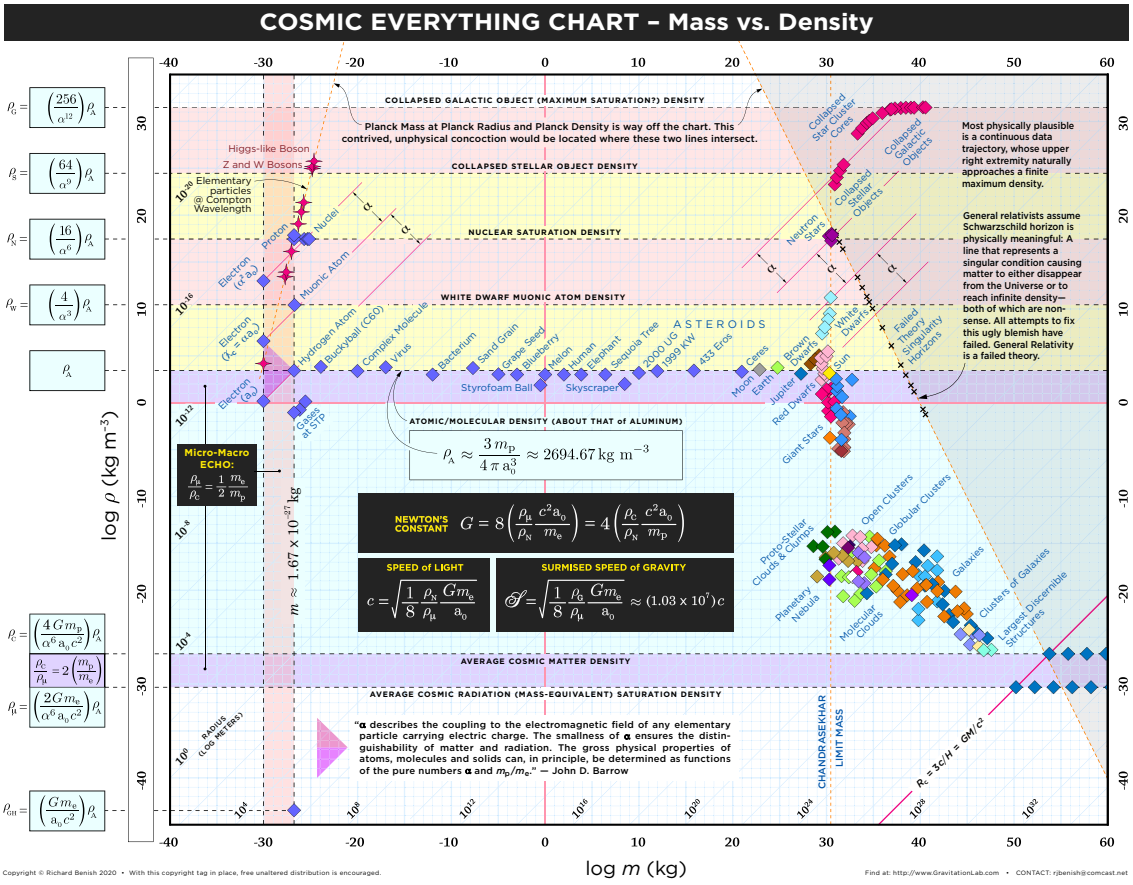


Figure 18: **Cosmic Everything Chart**. With data points gotten from the physics and astronomy literature, the wide horizontal stretch of more or less familiar material bodies (atomic/molecular density) is readily apparent. As masses approach those of stars, gravity's role begins to dominate, as seen on the vertical stretch near the Chandrasekhar mass limit. The absurdity of black hole singularities is strongly implied by the abrupt and wholly unnatural discontinuity at the Schwarzschild line. Data points above this line represent a logical, continuous alternative. The roles of the fine structure constant α, the proton/electron mass ratio, Newton's constant G, and the significance of key saturation densities are duly accentuated. Rotonians think of the Chart as a treasure map.

11. Interlude: Cosmology Sections in Progress

Finishing touches on the detailed story of the Rotonians' cosmological research are in progress. For the sake of expediency, presentation of the more locally applicable consequences of their gravity model will now come to a close. The Cosmic Everything Chart, a list of predictions, and a promise of more to come should suffice as a teaser for interested readers to absorb what's here, send feedback, and return for more. Stay tuned!

12. Predictions

As a parting shot I'll specify 11 consequences that correlate with or directly follow from the result of Galileo's Small Low-Energy Non-Collider experiment—*if* that result supports the Rotonian non-oscillation prediction:

1. Energy is not conserved.
2. Time only increases because space and matter also only increase.
3. Gravity is not an attraction between bodies.
4. The *cause* of spacetime curvature is the generation of space by matter.
5. The *curvature* of spacetime caused by the gravitational motion of matter and space indicates the existence of a *fourth spatial dimension*, as required for the seemingly three dimensions of space to have a *new direction to curve into*.
6. There is no such thing as a *static* gravitational field; everything moves.
7. Inertia is the same thing as gravity because that which causes *resistance* to acceleration in *one* direction is the accelerated generation of space and regeneration of matter in *every* direction.
8. The positive results reported by the LIGO collaboration will turn out to have been caused by something other than gravitational waves. What are commonly regarded as "black holes" are not really black. Dividing by zero yields only unphysical nonsense.
9. The Universe is infinitely old because its density remains constant as the whole of it, the whole, saturated, dynamically equilibrious continuum, exponentially expands.
10. Matter is an inexhaustible source of perpetual propulsion.
11. The expression for Newton's constant (Eq 16) may also be expressed as follows (showing more explicitly its connection to electromagnetism and quantum theory):

$$G = 8\left(\frac{\rho_\mu}{\rho_N}\cdot\frac{c^2 a_0}{m_e}\right) = \frac{4}{\pi\alpha}\left(\frac{\rho_\mu}{\rho_N}\cdot\frac{hc}{m_e^2}\right), \tag{17}$$

where α is the fine structure constant and h is Planck's constant.

The reasoning behind these predictions has been at least preliminarily discussed here in Part 1. In Part 2 we'll add more details from the cosmology and physics literature, provide more background support for the Cosmic Everything Chart, and consolidate the discussion of these matters, as found in my prior work. [40–44] The ultimate goal—in the spirit of Galileo—is to secure a plan to build and operate humanity's very first Small Low-Energy Non-Collider.

References

[1] Phipps Jr., Thomas E.: *Heretical Verities, Mathematical Themes in Physical Description*. (Classic Non-Fiction Library, Urbana, IL, 1986) p. 1.

[2] Benish, Richard: *Correspondence With Professors*, July 26, 2019 <http://vixra.org/abs/1907.0522>. Accessed December 11, 2019.

[3] Einstein, Albert: 'The Problem of Space, Ether, and the Field in Physics,' first published in *Mein Weltbild*. (Amsterdam, Querido Verlag, 1934). Reprinted in *Ideas and Opinions*. (Crown, New York, 1982) p. 282.

[4] Okon, Elias and Callender, Craig: 'Does quantum mechanics clash with the equivalence principle—and does it matter?' *European Journal for Philosophy of Science* **1** (January 2011) pp. 133–145.

[5] Barbour, Julian and Pfister, Herbert: 'Index of Different Formulations of Mach's Principle.' *Mach's Principle, From Newton's Bucket to Quantum Gravity*. Eds: J. Barbour and H. Pfister (Boston, Birkhäuser, 1995) p. 530.

[6] Jammer, Max: *Concepts of Simultaneity*. (Johns Hopkins University, Baltimore, 2006) p. 300.

[7] Einstein, Albert: *Relativity, The Special and the General Theory*. (Crown, New York, 1961) pp. 69–70.

[8] Einstein, Albert: ref [7] p. 80.

[9] Newton, Isaac: *Newton's Principia — Motte's Translation Revised: Sir Isaac Newton's Mathematical Principles of Natural Philosophy and His System of theWorld, Volume II*, Translated into English by A. Motte, in 1729. Revised translation by F. Cajori (University of California Press, Berkeley, 1962) p. 398.

[10] Einstein, Albert: 'Fundamental Ideas and Methods of the Theory of Relativity, Presented in Their Development,' originally published 1920. Reprinted in *The Collected Papers of Albert Einstein, Volume 7*. Alfred Engel, translator; Engelbert Schucking, consultant (Princeton University Press, Princeton, New Jersey, 2002) p. 139.

[11] Lilley, Sam: *Discovering Relativity for Yourself*. (Cambridge University Press, Cambridge, 1981) p. 272.

[12] Epstein, Lewis Carroll: *Relativity Visualized*. (Insight Press, San Francisco, 1988) pp. 65 ff.

[13] Gott III, J. Richard: *Time Travel in Einstein's Universe*. (Houghton Mifflin, New York, 2001) p. 85–86.

[14] Einstein, Albert: 'Physical Foundations of a Theory of Gravitation,' original publication 1913. Reprinted in *The Collected Papers of Albert Einstein, Volume 4*. Anna Beck, translator; Don Howard, consultant (Princeton University Press, Princeton, New Jersey, 1996) p. 197.

[15] Einstein, Albert: 'On the Relativity Problem,' original publication 1914. Reprinted in *The Collected Papers of Albert Einstein, Volume 4*. Anna Beck, translator; Don Howard, consultant (Princeton University Press, Princeton, New Jersey, 1996) p. 312.

[16] Einstein, Albert: Correspondence with A. Rehtz, July 12, 1953, as quoted by John Norton: 'What was Einstein's Principle of Equivalence?' in *Einstein and the History of General Relativity*. Eds: Don Howard and John Stachel (Birkhäuser, Boston, 1989) p. 21.

[17] Renn, Jeurgen and Sauer, Tillman: 'Heuristics and Mathematical Representation in Einstein's Search for a Gravitational Field Equation,' in *The Expanding Worlds of General Relativity*. Eds: Hubert Goenner, Jürgen Renn, Jim Ritter, and Tilman Sauer (Birkhäuser, Boston, 1999) p. 99.

[18] Stachel, John: 'The Rigidly Rotating Disk as the "Missing Link" in the History of General Relativity,' in *Einstein and the History of General Relativity*. Eds: Don Howard, and John Stachel (Birkhäuser, Boston, 1991) p. 48.

[19] Lorentz, Hendrik Antoon: *The Theory of Electrons, and its Applications to the Phenomena of Light and Radiant Heat*. (Dover, New York, 1952) pp. 195–196. (Original, 1909.)

[20] Glashow, Sheldon Lee: 'No Sacred Cows in Physics, an Interview with Sheldon Lee Glashow, Physics Nobel Laureate,' by R. Ramachandran: in *Frontline*, **25**, 02 (Jan.–Feb. 2008).

[21] Landau, L. D. and Lifschitz, E. M.: *Classical Theory of Fields*. (Addison-Wesley, New York, 1971) p. 247.

[22] Möller, Christian: *The Theory of Relativity, Second Edition*. (Clarendon Press, Oxford, 1972) p. 284.

[23] Rindler, Wolfgang: *Essential Relativity, Special General, and Cosmological*. (Van Nostrand Reinhold, New York, 1969) p. 152.

[24] Sagan, Carl: *Cosmos*. (Random House, New York, 1980) pp. 262–264.

[25] Abbott, Edwin: *Flatland*. (Harper-Collins, New York, 2001). (Original, 1884.)

[26] Ouspensky, Pyotr D.: *A New Model of the Universe*. (Dover, New York, 1997) pp. 75, 90. (Original, 1931.)

[27] Burger, Dionys: *Sphereland*. (Harper-Collins, New York, 2001). (Original, 1965.)

[28] Reichenbach, Hans: *The Philosophy of Space and Time*. (Dover, New York, 1958) pp. 280–283. (Original, 1927.)

[29] Swinburne, Richard: *Space and Time*. (MacMillan, London, 1968) pp. 152–155.

[30] Hobson, Mike; Efstathiou, George P. and Lasenby, Anthony N.: *General Relativity, An Introduction for Physicists*. (Cambridge, Cambridge, 2006) p. 35.

[31] Banchoff, Thomas: *Beyond the Third Dimension* (Scientific American Library, New York, 1990) p. 8.

[32] Bergmann, Peter G.: 'Open Discussion, Following Papers by S. Hawking and W. G. Unruh,' in *Some Strangeness in the Proportion, A Centennial Symposium to Celebrate the Achievements of Albert Einstein*. Ed: Woolf, H. (Addison-Wesley, Reading, Massachusetts, 1980) p. 156.

[33] Levin, Janna: *How the Universe Got its Spots: Diary of a Finite Time in a Finite Space*. (Anchor, New York, 2003). Levin asks: "Is there a theory beyond Einstein's that will avoid the ugliness of infinite singularities?" p. 86.

[34] Silk, Joseph: 'Rave Review for Hawking's New Book,' *Physics World* (November 8, 2001) < https://physicsworld.com/a/rave-review-for-hawkings-new-book/ > Accessed October 2, 2019. Silk's review contains the almost frightening assessment of GR's dubious prediction: "The classical [i.e., relativistic] view of a black hole is marred by one ugly feature: At the core of the black hole lies a singularity... [where] literally all hell may break loose."

[35] Benish, Richard: *Light and Clock Behavior in the Space Generation Model of Gravitation*. <https://www.researchgate.net/publication/265357823_Light_and_Clock_Behavior_in_the_Space_Generation_Model_of_Gravitation> Originally published in *Apeiron*, 2007. Accessed February 26, 2020.

[36] Schiller, Christoph: 'General Relativity and Cosmology Derived From Principle of Maximum Power or Force,' *Int. J. Theor. Phys.* (2005) **44** (9) p. 1629.

[37] Benish, Richard: *Maximum Force from Space Generation Model—with Annotation*. <vixra.org/abs/1908.0616> Accessed February 26, 2020.

[38] Epstein, Lewis Carroll: *Relativity Visualized*. (Insight, San Francisco, 1988) Epstein presents many illustrations of his tubular model on these pages: pp. 141–167.

[39] Schuster, Arthur: 'Potential Matter—A Holiday Dream,' *Nature*, **58** (1898) p. 367.

[40] Benish, Richard: *Cosmic Everything Chart*. <https://vixra.org/abs/1507.0155> Accessed February 26, 2020.

[41] Benish, Richard: *Rethinking the Universe*. FQXi Essay Contest entry, 2017. <https://fqxi.org/community/forum/topic/2838> Accessed February 26, 2020.

[42] Benish, Richard: *The Space Generation Model, Cosmic Numbers, and Dark Energy*. <https://vixra.org/abs/1503.0138> Accessed February 26, 2020.

[43] Benish, Richard: *Speed of Light and Rates of Clocks in the Space Generation Model of Gravitation, Part 1*. <http://vixra.org/abs/1406.0090> (Accessed February 26 2020).

[44] Benish, Richard: *Gravitational Clock: Near Space Proof-of-Concept Prior to Deep Space Measurement of G – Part I*. <https://vixra.org/abs/1612.0341> Accessed February 26, 2020.