FQXi Essay Contest 2017: How to connect mathematics and physics to life and consciousness?

Rethinking the Universe

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Abstract Human ideas of how life and consciousness relate to mathematics and physics are conditioned by the fact that we have lived our lives on a 5.97×10^{24} kg ball of matter. These ideas would arguably be different if we had evolved instead inside a large rotating world far from astronomical bodies. Contemplating the latter perspective provides some insight on how prevailing views may be in error and how to correct them.

1 Introduction

> *It is not true that developments in physics go ignored by professional humanists or by the common man. The basic facts get to us all and frame the way we think and even . . . feel.* [1]
>
> — John Updike

The well known fiction writer reflects, in the above quote, on what motivated his recent short story, *The Accelerating Expansion of the Universe*. The story's protagonist, Martin Fairweather contemplates the dismal eventualities of pre-1998 Big Bang cosmology: Inevitable *Big Freeze*, or equally deadly *Big Crunch*. The well known 1998 supernova observations are typically regarded as not only clinching the Big Freeze scenario, but as *accelerating* its progression. Insofar as the Big Crunch allows matter to reconstitute itself in a series of *Big Bounces*, Fairweather regarded it as providing at least some cosmic consolation. With this modicum of "comfort [now] taken from him," Fairweather descends "into a steady state—an estranging fever, scarcely detectable by those around him—of depression."

Do the empirical facts necessarily paint such a picture of doom? A more uplifting cosmic scenario emerges here by looking at the facts from a previously unimagined point of view. We explore the perspective of a hypothetical alien civilization by whose experience physical knowledge is built up in a different sequential order. Assembling the pieces in this new way results in a surprisingly different, yet coherent, organization and outlook. This outlook includes a radical reassessment of what life and consciousness have to do with mathematics, physics and the Universe. In particular, it includes a novel explanation for the otherwise enigmatic *arrow of time*. The validity of this new perspective can be unequivocally tested by performing a simple experiment.

2 Strategy

Humans are semi-autonomous physical things produced by the Universe. The *laws of physics are abstract mathematical things* produced by the minds of humans—motivated by their intent to survive in, to understand, and to *have fun* with their world. Solving problems by trial-and-error and playfulness go with each other; they both involve processing information; they both have survival value. If one thing doesn't work, *rethink* and try something else. Stretch the imagination till something works. Intent, choice, self-awareness—these are characteristics that differentiate complex life forms such as humans from primitive ones. Consciousness clearly tends to accelerate the course of evolution.

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Happily, an assortment of more or less bold rethinkings on such deep matters have been gathered here in one convenient forum. Though advances are to be acknowledged where found, to my mind none of these proposals—nor those found in the published literature—are directed or extended sufficiently beyond conventional thought. Being given the opportunity to chime in, my first deviation is to recognize what a beautiful thing this is! What a perfect expression of life and consciousness: to invite creative ideas from around the world regardless of criteria like academic stature. The neural net-like connectivity borne of humanity's interface with modern technology has facilitated this with impressive efficiency. Thanks to certain generous persons and the free tools at our disposal, professional academicians have now been joined by independent scholars worldwide. We have the striking metaphor of Planet Earth as a viable egg over which sperm-like ideas swarm and attempt to fertilize, to be received perhaps, as the most potent packet of transformation-inducing information.

Secondly, I will deviate by presenting—not a broad or tedious analysis about the meaning or significance of *information*, *emergence*, or *teleology*—but instead a particular idea concerning the interrelationships between space, matter, time and gravity, an idea that has the potential, I will argue, to transform the whole context of such general (or tedious) discussions. This potential is most clearly seen, I think, by framing the idea not as a rearrangement of physical facts by a single iconoclastic inhabitant of Earth, but as the *instinctively obvious* way to arrange the facts for an intellect that has evolved in the virtual absence of astronomical bodies of matter. The fiction-like aspect of the story is *by design*, to make it more fun, to loosen the mind into a state of playfulness. For we will then not be so inhibited by conflicts with seemingly well tested Earthian ideas. In the end a simple, feasible experiment gives *Nature* the final say on how these conflicts should be resolved.

3 Rotonians Again

Imagine a civilization of humanoid beings who have evolved on a huge rotating cylindrical world called Roton. Disregarding their origins, we suppose that Rotonians have sustained themselves and developed a technologically sophisticated culture over many eons. They were first introduced in my 2012 FQXi essay, *Rethinking Einstein's Rotation Analogy.* [2] Rotonians have a quantum-like theory much like the Earthian counterpart. So too for classical electromagnetic, and thermodynamic theories. Their basic theory of mechanics and motion accounts for effects due to the limiting speed of light, c, but it lacks a concept of *gravity*. Roton's mass/radius ratio is too small to make gravitational effects readily noticeable, and all astronomical bodies are so far away as to leave their coherence and existence a complete mystery—at least initially—to the Rotonians.

Most Rotonians reside on the inner wall of Roton's circumference, which rotates about its axis with sufficient speed to produce gravity-like effects very much like those on Earth's surface. A key distinction between Rotonians' and humans' primal experiences thus comes to light: Whereas Earthians live on the *outside* of a large curved surface, Rotonians live on the *inside* of a large curved surface. A few of the consequences of this difference will be explored in what follows.

Earthians acknowledge the large-scale motion of their planet's rotation, its revolution around the Sun, the myriad motions of Earth's geological structure and surface activity, and the intense atomic-scale motions of molecular matter. They nevertheless regard their most direct *gravitational* experience as being due to a *mysterious force* that leaves their planet as a *conserved and unmoving static thing*. Consistent with this interpretation is General Relativity's (GR's) *Schwarzschild exterior solution*. This utterly static representation of curved spacetime due to gravitating matter is commonly used to make predictions for the fields of the Earth and Sun.

Such descriptions are often presented in association with Einstein's view of spacetime as a *frozen block*, according to which different moments in time *coexist* as much as different locations in space. This is intuitively contradictory. Everyone knows everything moves, yet the icon of genius has proclaimed that the *time* inherent in the motion is an *illusion*.

When they visit Earth and learn of these views Rotonians will not be impressed because they are acutely aware of the fact and importance of the *perpetual motion* of their world. It is nothing like a frozen block. Roton's perpetual motion causes the rates of *clocks* to slow down, it affects the measurable speed of light, it periodically shifts the frequency of light from distant stars, it makes bodies released slightly "above the floor" of Roton *appear* to accelerate toward the floor, and it measurably flattens Rotonians' undersides. The latter measurements are made with *accelerometers*, which serve in the same capacity for measuring linear acceleration, as during their rocket-borne excursions beyond Roton. Two fundamental motion-sensing devices used by Rotonians are shown in Figure 1. To Rotonians *motion* is the essence of all things. Nothing is static.

According to the Earthian view of gravity non-zero accelerometer readings may or may not indicate the existence of real accelerated motion. Whether a given ac-

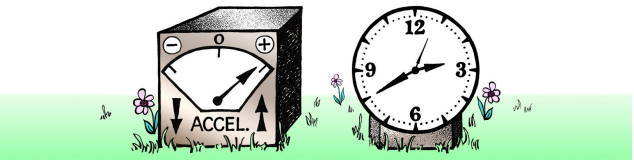

Fig. 1 Basic Motion-Sensing Devices: A *single* accelerometer measures acceleration along a given axis. Any *pair* of clocks (especially in conjunction with optical equipment) can measure a difference in speed—whether the clocks appear stationary or to be moving with respect to one another.

celerometer is regarded as accelerating or not depends less on its *physical* state than on the *mathematical* purpose at hand. Earthians have grown accustomed to the seeming reasonableness of a *relativity* to all motion (*at least locally*, as they say). There is no need to debate the value of this point of view. Instead, we emphasize that, prior to their soon-to-be-launched expedition, Rotonians have never doubted the *absoluteness* of the motion of their world. They have never found any reason to not believe that accelerometer readings always truthfully indicate their state of motion. Observations involving differences in elapsed times due to the motion of clocks only reinforce this conception of motion as an *absolutely* measurable thing. Anyone who disbelieves, equivocates, or exhibits confusion over the meaning of accelerometer readings is surely immature, unenlightened, or suffering some kind of mental disability.

Before telling of the Rotonians' voyage and visit to Earth, let's add a few more notes about their knowledge base. Rotonians have a firm grasp of Euclidean, non-Euclidean and hyper-dimensional geometries. Their observations of distant galaxies have yielded a redshift-distance relation and corresponding Hubble constant very nearly in agreement with the prevailing Earthian measurements. Rotonians have also measured the Cosmic Background Radiation (CBR), whose temperature they find to be in nearly exact agreement with the Earthian's COBE results.

4 Gravity for the First Time

For as long as they can remember, Rotonians' dreams have been filled with the distant myriad points of light—as an irresistibly alluring mystery. The journey that they've planned to solve it puts the fateful encounter on hold one last time, as the intrepid Rotonian rocket crew enters a state of stasis from which they will awaken as they near their far-off destination.

Please, dear reader, try earnestly to imagine what it would be like—having no prior experience with gravity as produced by astronomical bodies—to suddenly find yourself being overcome by one for the first time. The planet appears initially as a large disk in the distance. Since the Rotonians' rocket engines are off, they find it extremely bewildering—to the point of alarm—that such a monster appears to be accelerating, with an ever-increasing magnitude, straight toward them. What kind of gargantuan rocket must be powering this motion on the planet's far side?

In the nick of time the Rotonian explorers execute a soft landing. But their minds are seriously blown to discover that any angle of approach would have resulted in the same experience. *There is no far-side rocket.* Planet Earth was not only accelerating toward *them*. As indicated by accelerometers at locations all around the globe, the acceleration was and is in *every* direction. The situation becomes all the more confusing when the Rotonians learn that native Earthians think of their planet as a *static* thing; they do not believe their accelerometers. Earthians say the effect is caused by a force called *gravity*. Being compassionate and conscientious scientists, the Rotonians hear out the Earthians' story and duly mull over everything they can absorb from their literature on the subject.

Remaining unconvinced that Earthian ideas make more sense than their own, to settle the matter the Rotonians propose an experiment similar to one proposed by Galileo in 1632. [3] Arguably the simplest gravity experiment involving two bodies of matter, it entails simply letting one body fall into a hole through the center of the other. The needed apparatus may be called a *Small Low-Energy Non-Collider*. (See Figure 2.) The

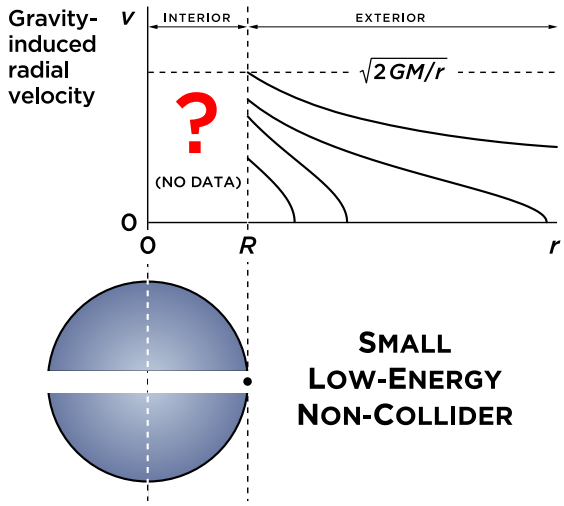

Fig. 2 Huge gap in gravitational data. Rotonians strongly urge filling it.

experiment's result would unequivocally support or refute one of the Rotonians' most basic physical assumptions. Up to now they have regarded as a fundamental truth (deeply ingrained by experience) that non-zero accelerometer readings are caused by one or both of only two things:

1. Rotation or
2. Propulsion.

If the Earthians' prediction for the experiment were to be confirmed, it would require adding to the list:

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

Based on their experience, and as shown in Figure 3, Rotonians predict that the dropped object will not pass the larger body's center. Whereas *Earthians presume to know*, based on their theories of gravity, that the smaller object will oscillate between the extremities of the hole.

In the general relativistic framework the oscillation prediction corresponds to the prediction that clock rates decrease to a central *minimum*. Rotonians find this to be grossly counterintuitive—especially as it corresponds to the prediction that length standards increase to a central *maximum*. Outside matter lengths and clock rates are affected by the same factor. Why should this pattern change inside matter? [4–6] What physical process could make clock rates decrease to a minimum, where *symmetry* arguments suggest the opposite? Most importantly, *these predictions have not been tested*. Earthians have simply failed to finish testing their gravity theories in this accessible physical regime. As preparations get underway to carry out this overdue experiment, Rotonians contemplate the implications of their prediction with regard to other physical and cosmological facts and ideas.

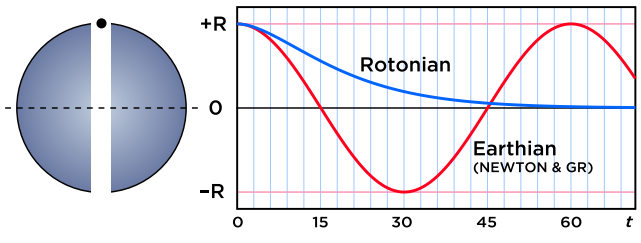

Fig. 3 Schematic showing competing predictions: Simple harmonic motion (red curve) vs. asymtotic approach to the center. The 60-minute oscillation period corresponds to a spherical source mass made of lead.

5 Interpreting the Evidence

A few key points based on Rotonian reflections on Earthians' gravitational theories and experience, combined with Rotonians' own prior research are summarized below. More detailed expositions on each point are available in the works cited.

5.1 Newton's Constant; Stationary Motion; Generation of Space

Rotonians are especially curious about how gravity's local magnitude depends on the quantity of matter and the physical constant represented thereby. As discussed in [2], the Rotonians also take great interest in Einstein's analogy concerning similarities between matter-produced gravity and the effects of *uniform rotation*. Uniform rotation has sometimes been referred to as a kind of *stationary motion* [7–9]. From well known facts and observations made in this connection, Rotonians suspect that Einstein's interpretation of his own analogy was backwards: The similarity of effects on uniformly rotating and gravitating bodies does not mean, as Einstein inferred, that rotating observers can think of themselves as being *at rest*. It means that (seemingly static) *gravitating bodies MOVE*.

Given that r is radial distance and ω is angular velocity, the rotational quantities $r\omega$ (speed) and $r\omega^2$ (acceleration) are analogous to the gravitational quantities $\sqrt{2GM/r}$ and GM/r^2, respectively—where M is the gravitating body's mass and G is Newton's constant. Earthians think of the latter as *negative* quantities, which refer to particular cases of *falling* bodies. Whereas Rotonians think of them as positive quantities, which refer to the gravitating body itself.

Newton's constant thus requires reinterpretation. Before giving the Rotonian version, let's first give a novel description of the Earthian version. Denoting generic length, mass, and time as L, M, and T, respectively, the dimensions of G are L^3/MT^2. This can be expressed verbally as *acceleration of volume per mass*. Big Bang cosmology may be the best context in which to see the volumetric sense of this. The Big Bang blows space into existence, while gravity "tries" to suck it back out. The *discontinuousness* of matter and space is also clearly seen in this context: The distances that separate discontinuous chunks of stuff (galaxies) from one another supposedly increase, as ever more space is created. But if the average cosmic density were sufficiently great, the galaxies' gravity would not only brake, but reverse the Big Bang's expansion. Gravity would suck all space back out of existence.

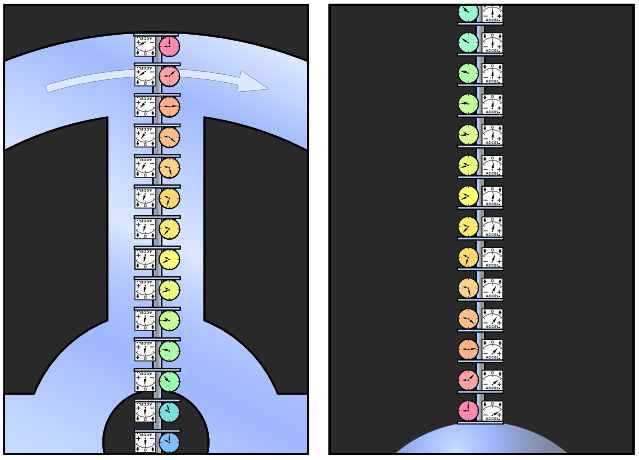

Fig. 4 The range of constant non-zero accelerometer readings combined with the range of constant clock rates indicates that both of these systems—rotational and gravitational—are undergoing *stationary motion*. Stationary motion of the rotating system is *through* space. Whereas stationary motion of the gravitating system is evidently *motion OF space*. Spacetime *curvature* caused by this motion implies a *fourth spatial dimension*.

Rotonians think this picture is backwards in many ways. Interpreting G as a positive quantity, it now represents the *generation of space* by matter. The envisioned process includes the space *occupied* by matter such that, as matter generates space, it also regenerates itself. This is what the accelerometers and clocks on the right side of Figure 4 seem to be saying. The locally measurable magnitudes of this process are expected to vary with location because of the inhomogeneous distribution of matter. For these motions to be actually taking place without a rapid decoherence of matter, requires space to be not merely three-dimensional, but four-dimensional. It requires matter and space to be not fragmentarily discontinuous as Big Bang cosmology (and other fields of physics) would have it.

Rotonians infer, rather, that matter and space (and time) are ultimately continuous and *interdependent* with one another. [4] Pursuing to where it leads the simple idea that accelerometers always tell the truth, Rotonians come to suspect that *matter is an inexhaustible source of perpetual propulsion*. [6] Earthian objections based on the energy conservation law are duly noted. In response, Rotonians point out that the law has not been tested exactly where they predict it to fail, i.e., inside matter. The truth or falsity of Rotonian intuitions about gravity and energy conservation can be discovered by probing gravity-induced radial motion *through the centers* of material bodies.

5.2 Speed of Light and Spacetime Curvature

The rates of clocks attached to Earth depend on the gravity-induced speed $\sqrt{2GM/r}$. For the surface radius $r = R$ this is the speed that the surface would have with respect to an object falling radially from (just this side of) infinity. Rotonians call the latter trajectories *maximal geodesics*. As suggested by the rotation analogy, the state of motion of points attached to the gravitating body are seen as a combination of *stationary outward velocity* (clocks) and *stationary outward acceleration* (accelerometers).

Rotonians acknowledge the need to accommodate the limiting speed of light in all cases involving motion. Happily, Earthian archives include accounts of how this limiting speed relates to motion under constant acceleration—a discovery that Rotonians had also made on their own. The limit is expressed as the speed $v(t)$, acquired by a rocket that is propelled for a long coordinate time t, under constant acceleration a, as measured by an onboard accelerometer:

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

Replacing the kinematic (*through* space) quantity *at* with the gravitational (*of* space) quantity $\sqrt{2GM/r}$ yields a variety of interesting results:

$$V_{\rm S} = \frac{\sqrt{2GM/r}}{\sqrt{1 + 2GM/rc^2}} = \sqrt{\frac{2GM}{r + 2GM/c^2}} \,. \tag{2}$$

This speed approaches c, not with increasing time, but with increasing M/r ratio. Being satisfied to have deduced this limit for gravitating bodies, Rotonians think it means that there are no black hole singularities (nor horizons). [6] Clocks do not stop, time does not turn to space, space does not turn to time, matter does not pop out of the Universe (or become infinitely dense). Rather, all of spacetime is well-behaved (singularity-free) and continuous.

To establish that the Rotonian interpretation of gravitational time dilation (among other "relativistic" effects) is empirically viable, Rotonians compare the standard Schwarzschild metric coefficient with what would be its Rotonian replacement. Squaring $V_{\rm S}$, in Eq (2) yields the second term here:

$$\left(1 - \frac{2GM}{rc^2}\right)^{-1} - \left(1 + \frac{2GM}{rc^2}\right) = \frac{4G^2M^2}{r^2c^4(1 - \frac{2GM}{rc^2})} \,. \tag{3}$$

The difference is immeasurably small for all weak-field cases. The significant difference for strong-field cases motivates the Rotonians to predict that evidence recently published by Earthians as indicating a collision of black holes will eventually prove to be no such thing. Earthians' acceptance of this evidence—being the product of *just one* (enormous and deeply invested) team of researchers—is regarded by Rotonians as premature wishful thinking because the alleged gravitational wave signals were not corroborated with simultaneous electromagnetic signals.

5.3 Fourth Dimension of Space

According to the Earthians' static picture of gravity, there are only three spatial dimensions. Including time, spacetime is supposed to be $(3+1)$-dimensional, where the $+1$ represents time as a dimension. In the course of combing the vast Earthian literature about the possibility of spatial dimensions greater than three, Rotonians sometimes experienced flickers of hope at finding an echo of their own thoughts on the matter. These hopes all fizzled out. Many convoluted, unphysical, and observationally inconsequential ideas are on the books, but the simplest and most physically plausible possibility appears to have been overlooked.

When a 1-D line begins to *curve*, it enters a *second* spatial dimension. When a 2-D surface begins to *curve*, it enters a *third* spatial dimension. Evidence abounds that *the geometry of our seemingly* $(3+1)$*-D world is curved*. Rotonians regard this simple fact as an indication that the world also possesses at least *four* spatial dimensions. Consistent with the pattern described above, by virtue of its manifest curvature, seemingly $(3+1)$-dimensional spacetime requires a fourth spatial dimension *to curve into*. To Rotonians it is obvious that gravitational curvature cannot arise from a static thing. Something must be *happening*—something must be *moving*—to make it so.

Graphic models of $(4+1)$-dimensional spacetime are limited. Figure 5 represents one facet of the endeavor by compounding the rotation analogy, in a sense, back to gravitating matter. We only "see" a cross-section of

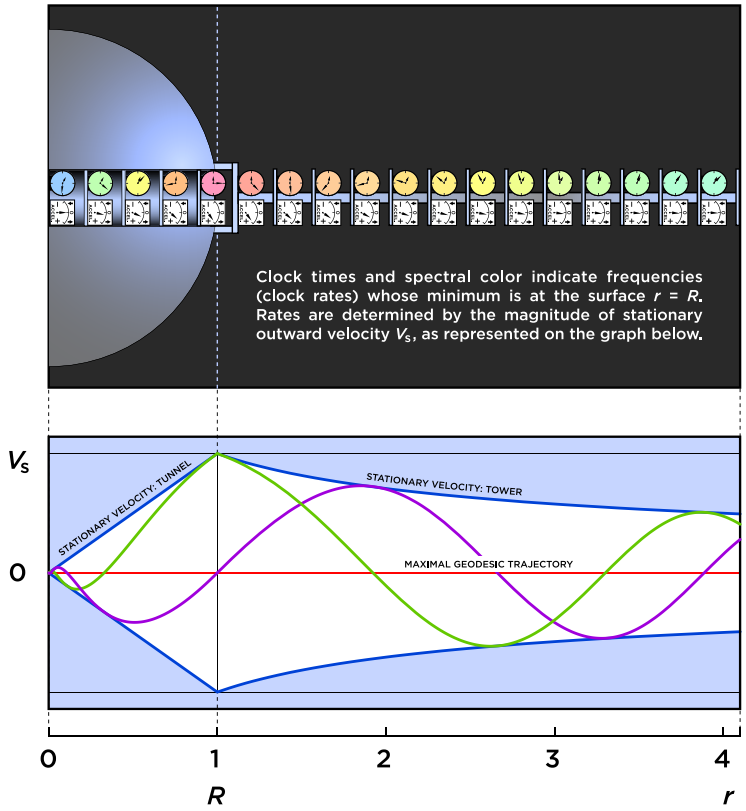

Fig. 5 Tubular model of $(4+1)$-dimensional radial stationary motion. **Top:** Physical circumstance represented in graph below; i.e., a gravitating body and an imaginary tower attached to its surface. **Bottom:** V_s-axis represents stationary outward velocity; i.e., the stationary motion of space—into 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.

the world we inhabit. This cross-sectionally seen fourth dimension of space extends—by gravity—*radially outward*, but is imagined in Figure 5 as a rotational projection perpendicular to the page. By this means Rotonians conceive a range of speeds and accelerations undergone by seemingly rigid gravitating bodies as being analogous to those undergone by seemingly rigid rotating systems. In the present case, the motion is not *through* space, it is motion (generation) *OF* space. Its *curvature* indicates that it is $(4+1)$-dimensional.

Abiding by Einstein's mathematical theory, general relativists typically insist that the *intrinsic* curvature of $(3+1)$-dimensional spacetime is sufficient to describe our world. Earthians' assumption of block-time staticness—with its reversible arrow of time—poses a huge mental block which prevents conceiving that gravitating bodies may be undergoing perpetual motion into (or outfrom) the fourth dimension of space.

6 Cosmological Implications

Rethinking the local effects of gravity from a Rotonian perspective leads to simple cosmological consequences that contrast sharply with the Big Bang. Though other critics of standard cosmology have pointed out serious weaknesses therein [10–12] viable alternatives appear not to be forthcoming.

Though more development is needed, the Rotonians' skeletal model has been fleshed out sufficiently well to motivate further exploration. Happily, one of the new model's cornerstones is not controversial: The *clock-like nature of matter* by contrast with the *timelessness of light*. [13] When combined with the new Rotonian model of gravity, this juxtapostion explains the redshift-distance relation (which is often touted as the strongest piece of evidence for the Big Bang).

Among the other elements comprised by the Rotonian model, we have parts of GR, parts of quantum theory, certain well known "Large Numbers coincidences" (suggesting a connection between these extremes [14, 15]) and their new conception of gravity. Rotonians see their model as having the potential to reveal a new kind of *unification* that makes standard ideas of unification look rather fragmented.

Briefly described, the model involves a (deSitter-like) exponential expansion—not of only discontinuous (or empty) space, but of space and matter combined such that the average density is a constant. A *steady state* is maintained, not by the discontinuous appearance of new particles, but by the perpetual increase in mass generated by all bodies that already exist. The *process* whereby matter and space increase in the same proportion, is gravity. If the result of Galileo's experiment supports the Rotonian prediction, a variety of profound and persistent puzzles in physics and cosmology will evaporate. A few of these consequences and their connection to standard physical ideas are briefly discussed in the Appendix.

Because of how compactly it can be expressed and because of its potentially profound implications, one of these consequences will be presented here. The Rotonians have found an expression by which Newton's constant is related to the other constants in physics—extending, in fact, from atomic nuclei to the CBR, and everywhere in between. Given that ρ_μ is the mass-equivalent of the CBR energy density, $\rho_{\rm M}$ is the average cosmic matter density, $\rho_{\rm N}$ is the nuclear saturation density, a_0 is the Bohr radius, $m_{\rm e}$ is the electron mass, and $m_{\rm p}$ is the proton mass, the Rotonians find:

$$G = 8\left(\frac{\rho_\mu}{\rho_{\rm N}}\cdot\frac{c^2\mathrm{a}_0}{m_{\rm e}}\right) = 4\left(\frac{\rho_{\rm M}}{\rho_{\rm N}}\cdot\frac{c^2\mathrm{a}_0}{m_{\rm p}}\right). \tag{4}$$

Rotonians suppose it is natural to relate the densities shown here to one another—as graphically indicated in Figure 6—because, among other reasons, it solves the *hierarchy problem*. Sometimes stated as the question: "Why is gravity so weak compared to the other forces?" the Rotonian answer is: Gravity appears so weak because the Universe is so large. Nuclei *saturate* at the scale where the strong and electromagnetic forces balance. Molecules *saturate* over the range at which positive and negative atomic/ionic charges are in balance. And the Universe gravitationally *saturates* at the cosmic scale where global space and matter are in dynamic equilibrium with the CBR. The latter speculation becomes more plausible by considering the fact that the relation

$$\frac{\rho_\mu}{\rho_{\rm M}} = \frac{1}{2}\frac{m_{\rm e}}{m_{\rm p}} \tag{5}$$

is at least very nearly true. Rotonians assume it is exactly true—and always will be.

7 Conclusion

Rotonian attempts to understand the gravity of a planet like Earth have led to a whole new cosmology: A Universe in which *the arrow of time only increases because the arrows of space and matter also only increase*; a Universe which, in its eternal unfolding, must surely be teeming with life. The very existence of life in an edgeless and eternal Universe suggests that the whole

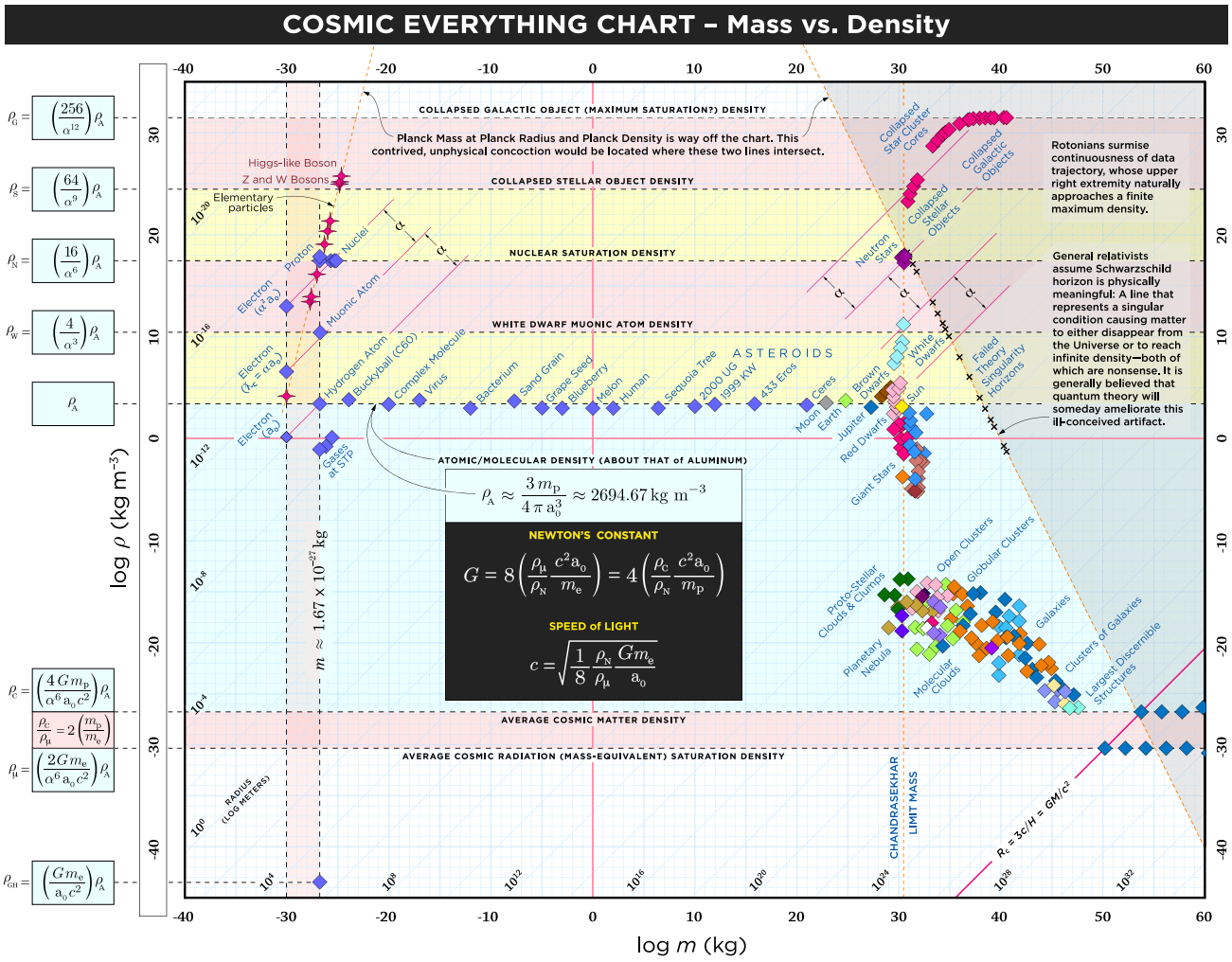

Fig. 6 All data points are derived from standard literature. Bodies of matter whose masses and densities are greater than neutron stars cannot be accommodated by GR. The old dream that quantum theory will someday rescue GR in this regime remains unfulfilled; singularities remain theoretical inevitabilities. The Schwarzschild horizon line cuts unnaturally across the more sensible trajectory proposed by the Rotonians. Collapsed objects indicated thereon all maintain finite density, which approaches a postulated *maximum*, as shown. Notice the hierarchy of key densities and how their values depend on the fine structure constant α.

of it is, in some sense, *alive*. Its *purpose*, if one may be surmised, is to become aware of itself. Human beings appear to be the local agents of this never-ending multi-dimensional growth.

It seems to be a cosmic fact that critical junctures will arise, at which certain other facts about the physical Universe—utterly key pieces of the puzzle—must be discovered and put properly into place, to enable further progress. If only to ascertain the viability of this radical new spark of cosmic hope, Martin Fairweather would therefore, I suppose, be as eager as the Rotonians to fill the gap in our empirical knowledge of gravity, to discover whether or not the Rotonian perspective rings true. If believing accelerometer readings is a mistake, then the result of Galileo's experiment will presumably vindicate those who have believed instead in gravitational attraction.

Whereas if the Rotonian prediction is supported, it would then become evident that humanity is in the process of flipping the biggest gestalt switch yet to be flipped on Planet Earth. We will at long last have begun to thaw the huge and ancient block of gravitationally static matter that has for so long misguided our imaginations. Together and forever we could then ride off in all directions—whether consciously intending to or not.

Appendix

A Details and Derivations

A.1 Arrows, Non-Colliders, and Energy Conservation

Rotonians suspect that Earthians' confusion over the *arrow of time* is due to their disbelief in accelerometer readings, which goes with their upside-down assessment of the *arrow of gravity*. The result of Galileo's experiment would convincingly establish that gravity points downward and is dynamically reversible, or that it points upward and is dynamically irreversible.

Suppose we make a video of a Small Low-Energy Non-Collider in action. If the result corresponds to a cosine curve as in Figure 3, backward would be indistinguishable from forward, which would mean gravity points downward. But if the video reveals a hyperbolic secant-like asymptotic approach to the axis—as predicted by the Rotonians—a backward replay of the video would make no sense. The cosine curve is reversible, the *sech* curve is not. This is due, in the latter case, to the stark violation of energy conservation. The falling object appears to lose energy because energy is irreversibly increasing (space is being generated) all around it.

Matter, space, gravitational energy, and time all point upward, they all increase. Falling accelerometers always register zero acceleration, indicating that they are never "pulled downward" toward or past the centers of gravitating source masses. The energy conservation law is an *assumption* that has *never been tested with respect to gravity-induced radial motion through the centers of gravitating bodies*. What are we waiting for?

A.2 Equivalence Principle

Rotonians predict that Equivalence Principle tests will never find a violation because gravity is not an attraction. In a $(4+1)$-dimensional sense, "the floor [really does] come up." The apparent identity of inertia and gravity is because they both arise from the same physical process. That which gives a body of matter its *resistance* to acceleration in *one* direction (inertia) is the accelerative $(4+1)$-dimensional generation of space in *every* direction (gravity).

A.3 Cosmological Constants

Einstein's cosmological constant, Λ represents a perpetual generation of ever more space *out of itself, independent of matter*. Such a thing goes with—by way of contrast—a conception of static, discontinuous chunks of matter. Gravity—produced *somehow* by this matter—is supposed to "try" counteracting the effect of Λ by sucking the space between static chunks of matter back out of existence. So say Einstein's field equations.

One of the first cosmological solutions of GR by Willem deSitter described a space empty of matter subject only to the action of Λ. Its expansion was exponential, inspiring Robertson and Noonan to call it:

> the only non-static stationary model . . . [because although] . . . the fundamental world-lines expand away from each other. . . they also present the same appearance at any cosmic time.[16]

Once again we meet opposing theoretical arrows: Λ points out; gravity points in. A hybrid deSitter model contaminated by attracting matter would exhibit a disruption to the perfect exponential expansion as long as matter's gravitational energy density remained a significant fraction of the total. In the end—it is often supposed—the exponential expansion of space wins out and dooms the density and temperature of cosmic matter to approach zero.

If, on the other hand, the arrow of gravity were actually outward; if matter, space and time were interdependent so that gravity is seen as the process by which matter $(4+1)$-dimensionally produces space, then Λ makes no sense. Matter produces only enough space to keep the proportion constant. We end up with a non-static stationary model full of (i.e., *saturated* with) gravitating matter. (See Figure 6.) Problem solved.

A.4 Redshift-Distance Relation and More Constants

According to many authors, including Einstein [13], and as may be deduced from the truth value of quantum theory, *matter is clock-like; light is timeless*. From the wave-nature of atomic matter, deBroglie deduced a relation between the mass and frequency of material particles:

$$f = \frac{mc^2}{h}\,, \tag{6}$$

where h is Planck's constant. The Rotonians apply this expression to cosmology as follows. They first assume a cosmic scale length something like $R_{\rm C} = GM_{\rm C}/c^2$. They envision a cosmically "detatched" observer who uses a frozen scale to measure the exponential increase of all lengths, including $R_{\rm C}$. Whereas observers who participate in the cosmic flow use measuring rods that find $R_{\rm C}$ and other cosmic distances, $r_{\rm o}$ to be constants. The first observer's measurements are thus related to the other as

$$r = r_{\rm o}\exp\left(\beta t\right), \tag{7}$$

where t is time and β is yet to be defined.

Volumes thus increase by the *cube* of Eq (7). For the density to remain constant, *masses* must also increase by the cubed factor: $m = m_{\rm o}\exp\left(3\beta t\right)$. Coming back to the deBroglie relation, Rotonians suppose it means that cosmic *frequencies* also increase by the same exponential relation. Probing deep space means looking to a time when clocks were slower because masses were smaller. Omitting a few steps, these ideas lead to a redshift-distance law:

$$z = \exp\left(\frac{3r}{R_{\rm C}} - 1\right)\,. \tag{8}$$

Light from distant galaxies retains the energy it had upon emission because light is timeless. But all clock-like matter increases, so the farther light travels, the more redshifted it gets. Curiously, deSitter's cosmological model is sometimes regarded as yielding a similar law for (partially) similar reasons—sometimes called the *deSitter effect*.

By use of standard procedures for defining a critical density and for relating a scale factor like $R_{\rm C}$ to the Hubble constant, Rotonians pursue this line of thought to their own predictions for these parameters. Again skipping a few steps, suffice it for our purposes to point out that the matter density parameter comes out as $\Omega_{\rm M} = 2/9$ and the Hubble constant comes out as $H_{\rm SGM} \approx 64$ km/sec/Mpc. Unlike their Big Bang counterparts, these are both *bona fide* constants in the Rotonian model. (See [4, 15].)

A.5 Does Matterless Energy Gravitate?

Before discussing how the Rotonians would connect these cosmical constants to atomic physics, another consequence of their gravity model that conflicts with GR should be mentioned.

Because of the clock-like nature of matter and the timelessness of light, Rotonians regard *active gravitational mass* as being manifested only by *matter-like* energy. Generation of space unfolds at a *rate* that depends on the clock (body of matter) doing the generating. Photons, of course, travel on null geodesics of spacetime. But, Rotonians reason, they do not generate space (gravitate) because they are timeless. Furthermore, it follows that, although bodies that move *through* space at near the speed of light manifest an *increase in inertia*, this would arguably correspond to a proportional *decrease in active gravitational mass*. Slower clocks, less gravity—whether the clock-slowing is due to motion through space or of space.

If this reasoning is accurate, it means that the inertia/gravity equivalence discussed in A.2 requires qualification, which is omitted for brevity. Though representing an obvious and significant departure from GR, Rotonians argue that their approach is more physically reasonable. In this extreme regime it is also difficult to test, though possibly could be by future astrophysical observations. The comparative intuitiveness of the Rotonian approach may be illustrated by negation, as it does not entail awkward questions such as this: How is a photon supposed to *attract* other photons by "exchanging gravitons" when both photons and gravitons travel at the speed of light?

A.6 Unification?

Prevailing Earthian conceptions of *unification* make little sense to the Rotonians. Earthians say they want to "marry" quantum theory with GR, even though they have not finished *testing* GR over the most ponderous half of the gravitational Universe, inside matter. This courtship has been pursued for decades by thousands of mathematical scholars. Yet it remains an unfulfilled dream. Rotonians suspect it is not a math problem. It is a conceptual problem.

Earthian theorists conceive an *initial* state of (nearly?) infinite temperature and density from which discontinuous chunks of stuff and fragmentarily separate forces explosively "freeze out"—becoming the state we see today. Unification is supposed to be found at the *Planck scale* of size, time, density and temperature, which resembles those initial conditions when the strengths of the separate forces are presumed to have been the same.

The Rotonian view is much simpler because it holds that *unification is to be found in ordinary conditions of everyday physical reality*. Unification means understanding the interdependence of the physical elements of space, matter, and time. It means being able to express the physical constant pertaining to the large scale behavior of the cosmos, i.e., G, in terms of the constants pertaining to nuclear, atomic and electromagnetic phenomena.

At an early stage of this exploration, Rotonians resonated with the published speculations that the similarity in magnitude between the ratio of the electric to gravitational forces in atoms and the ratio relating the respective *sizes* of atoms and the Universe, exists *for a physical reason*, not just by coincidence. [14, 15] This must indeed be the case in a Universe that dynamically maintains a stationary state.

An important clue attained impressive concreteness when the COBE measurements of the CBR were announced. Unrecognized by standard theorists is that the energy density of the CBR forms a curious ratio when its mass-equivalent is compared to the average cosmic matter density:

$$\frac{\rho_\mu}{\rho_{\rm M}} \approx \frac{1}{2}\frac{m_{\rm e}}{m_{\rm p}} \tag{9}$$

Uncertainty in the actual value of $\rho_{\rm M}$ at least partly explains why this correspondingly uncertain connection to $m_{\rm e}/m_{\rm p}$ was not noticed. Rotonians, on the other hand, were looking for something like this, since both relationships represent a kind of ethereal gateway, or transition zone, connecting matter and light—one in the microcosm, one in the macrocosm.

Be that as it may, the assumption that this expression is true fixes a cosmic matter density, from which a scale factor can be calculated (as implied in A.4). The fine structure constant then appears in the ratio between electric and gravitational forces in the hydrogen atom, and the cosmic scale factor and the Bohr radius:

$$\frac{F_{\rm E}}{F_{\rm G}} = \frac{2}{\alpha}\frac{R_{\rm C}}{{\rm a}_0}\,. \tag{10}$$

Rotonians think the Cosmic Everything Chart in Figure 6 speaks volumes to the emerging pattern. In the end we get a variety of suggestive relationships crowned, perhaps, by these equivalent ways of quantifying the local/universal acceleration of volume per mass:

$$G = 8\left(\frac{\rho_\mu}{\rho_{\rm N}}\cdot\frac{c^2{\rm a}_0}{m_{\rm e}}\right) = \frac{4}{\pi\alpha}\left(\frac{\rho_\mu}{\rho_{\rm N}}\cdot\frac{hc}{m_{\rm e}^2}\right) = \frac{\alpha^3}{2}\left(\frac{{\rm a}_0}{R_{\rm C}}\cdot\frac{c^2{\rm a}_0}{m_{\rm p}}\right)\,. \tag{11}$$

Among the measured constants in Eq (11) nuclear saturation density is the least well known ($\Delta \approx 6\%$). But the values sometimes given for this ($\rho_{\rm N} \approx 2.84\times10^{17}$ kg/m^3) make the Rotonian expression for G very nearly true. Note that the only model-dependent constant in Eq (11) is $R_{\rm C}$. Since the rest of them are measured, these relationships are nearly true—whether by coincidence or because they are profoundly meaningful.

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