How Time Dilation's ‘Antigravity’ Effects Impact the Expanding Universe

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Abstract

We outline how the cosmos’ accelerating expansion, diminishing over time, can be explained using the 1915-16 Einstein/Schwarzschild metric in the geodesic equation without requiring Dark Energy.

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Roger Babson, 1898 MIT Bachelor of Engineering, was author of the highly successful investment-advisory Babson's Reports and scores of influential books and articles on investment – which drew their inspiration in part from Newton's Third Law of Action and Reaction and from Newton's Law of Gravity. He founded the Gravity Research Foundation in 1949 with the hope that a better understanding of gravity would lead to the invention of antigravity devices that might shield one from severe falls or drowning. As a teenager Babson tragically lost his older sister, and then later lost a grandson, to drowning.

Babson's 1894-98 exposure to Newtonian physics at MIT predated Einstein's 1905 Lorentzian modification of Galilean-Newtonian relativity – which implies that moving clocks tick more slowly than a clock at rest – and also Einstein's 1907 prediction that clocks in a stronger gravitational field tick more slowly than ones in a weaker gravitational field. While time-dilation effects caused by speed and by variation of gravitational field strength are exceedingly small for speeds much less than the speed of light, *c*, and for the gravitational field-strength variations between the earth's surface and higher altitudes, atomic clocks have confirmed speed time dilation for speeds as low as twenty miles per hour, which is less than a ten-millionth of *c*, and confirmed gravitational time dilation down to 'altitudes' of less than 15 inches. Time dilation *reduces* a body's observed speed, its observed distance traveled per differential time. Consequently, it *also alters* that body's observed acceleration – in particular its observed acceleration produced by gravity.

A body released from rest in a *weak* constant gravitational field will initially fall with constant acceleration as with Newtonian gravity. However, as its speed increases, the Lorentzian time dilation that increased speed produces slows it down very slightly relative to Newtonian gravity's prediction. Thus, the effect on that body of Lorentzian speed time dilation *opposes* that of Newtonian gravitational acceleration. While this 'antigravity' effect of speed time dilation is initially very small for a body released from rest in a weak constant gravitational field; once enough speed is attained, it upends Newton's prediction of perpetual acceleration of a body in a gravitational field because Lorentzian (i.e. – Special) Relativity won't allow the body to ever reach the speed of light, *c*. This very slight 'antigravity' effect of speed time dilation is thus seen to be the harbinger of nature's speed limit.

If a constant gravitational field where the body is released from rest is *strong* enough, on the other hand, then the 'antigravity' effect of the consequent strong gravitational time dilation dominates from the start, and therefore – seemingly paradoxically – a strong enough gravitational field only weakly accelerates a body from rest. And once it is moving fast enough, that body's acceleration again diminishes as time dilation grows larger. The constant gravitational fields considered above are adequate approximations only in sufficiently small regions. A spherically-symmetric gravitational field, which characterizes a spherically-symmetric distribution of gravitating matter, is a more plausible simple model for the universe as a whole. For such a spherically-symmetric expanding universe model, gravitational time dilation was an overwhelming influence *when that universe was small enough*. This, of course, has a profound effect on cosmology.

Before considering the consequences of gravitational time dilation for an expanding spherical universe model, let us explore the behavior of a wave packet of light radially approaching Earth's spherical gravitational field from afar. The speed of such a wave packet can never exceed *c*, so the contest between a wave packet's gravitational acceleration toward the Earth and its slowing down due to time dilation is either a tie, or is won by the slowing effect of gravitational time dilation. One can calculate the result of this tug-of-war using the multi-component gravitational potential (i.e. – the gravitational metric) which was perturbatively approximated by Einstein[1] in his celebrated November 18, 1915 paper where he worked out Mercury's perihelion precession, and obtained exactly by Karl Schwarzschild[2] in his January 13, 1916 paper. Then, Johannes Dröste[3] in his December 8, 1916 doctoral thesis and David Hilbert[4] in a December 23, 1916 paper *both* showed thereby that this gravity vs. time dilation tug-of-war *is* ***won decisively*** *by the slowing effect of gravitational time dilation*; at large distances from the Earth, a radially approaching wave packet of light is accelerated **away** from it *twice as strongly* as a body at rest at those distances is radially accelerated **toward** the Earth. Ergo, the *net effect* on a *wave packet of light* of Newtonian gravity **plus** gravitational time dilation is REPULSIVE ACCELERATION! So, the ‘antigravity’ effect of gravitational time dilation *on light* is **far in excess** of the *shielding* of Newtonian gravity that Roger Babson hoped for.

A spherical gravitational field's **slowing down** below *c* of radially *incoming* light and its **speeding back up** to *c* of radially *outgoing* light is similar to the effect on light of a transparent sphere of optically refractive material such as glass. Thus just as an oblate glass spheroid can serve as a magnifying lens, the roughly similar shape that is a characteristic of many galaxies can serve as a gravitational magnifying lens for the images of more distant galaxies. This ‘gravitational lensing[5]’ magnification arising from the ‘antigravity’ effect of gravitational time dilation **on light** has become a very useful tool in astronomy.

Furthermore; the independent work of Dröste and of Hilbert in December, 1916 shows that a spherically-symmetric gravitational field repels *not only* a distant radially-traveling light packet, *but also* repels ***any*** body traveling toward or away with a speed exceeding $c/\sqrt{3}$ (~58% the speed of light), which corresponds to a Doppler spectral redshift z of almost one (z = 0.931852). Since confirmed redshifts of currently observable receding galaxies now range up to slightly past z = 14, the December, 1916 works of Dröste and of Hilbert imply that most of the currently visible expanding universe accelerates **away** from us. In effect, their work predicts that the *expansion* of the universe **accelerates**. This spectacular ‘antigravity’ phenomenon was independently confirmed by the teams of Riess[6] and Perlmutter[7] in 1998 studying the apparent luminosities of Type Ia supernovas in increasingly distant galaxies, and their observational work won the Nobel Prize[8]!

Unfortunately, the December, 1916 theoretical works of Dröste and Hilbert aren’t recounted in most gravity textbooks, though they follow directly from the same spherically-symmetric gravitational metric Einstein used in his watershed November 18, 1915 paper to obtain the correct values of both Mercury's perihelion precession and the deflection of starlight by the sun's gravity. A key clue to ***why*** Mercury's elliptical-orbit perihelion *precesses* is that the planet's gravitational time dilation and speed time dilation are both at their maximum values at the planet's closest approach to the sun, namely its orbit perihelion. And notably, *time dilation as well* **underlies** the December, 1916 ‘antigravity’ predictions of Dröste and Hilbert for distant bodies moving radially in a spherically-symmetric gravitational field at speeds that are a significant fraction of *c*.

Because almost all gravity textbooks **omit** the December, 1916 Dröste/Hilbert results, the 1998 observations that the universe's expansion accelerates prompted perplexity among theorists instead of quiet satisfaction that a 1916 prediction had been validated. Though people talked about a crisis in cosmology; physicists did not see that those results invalidated assumptions of the prevailing model, so they resurrected Einstein's 1917 addition of a cosmological constant, but with a **positive** sign, ***despite*** the well-known fact this doesn't permit recovery of Newtonian gravity theory when gravitation is static and weak and the relative speeds are much less than *c*. Furthermore, adding a positive cosmological constant to the Einstein equation – ostensibly as the effect of ‘Dark Energy’ – renders the acceleration of the universe's expansion **insensitive to the flow of time**, whereas the 1916 Dröste/Hilbert work’s ‘antigravity’ phenomenon is *an integral aspect* of standard Einstein/Schwarzschild gravity, so it predicts that the acceleration of the universe's expansion ***diminishes*** *as the cosmos expands*. Data from the Dark Energy Spectroscopic Instrument[9] (DESI) is clearly more compatible with the acceleration of the universe's expansion diminishing over time than with the *constancy* of that phenomenon.

Before the ‘Dark Energy’ idea debuted in the wake of the 1998 discovery that the universe's expansion is accelerating rather than decelerating (as *anticipated by*

Raychaudhuri[10] in 1979 after negative 'deceleration parameters' first appeared), most cosmologists applied the FLRW metric form, which uses essentially Newtonian gravity, thereby excluding gravitational and speed time dilation. The Newtonian character of the FLRW metric implies that galaxies receding from the Earth *decelerate* no matter how fast they recede, whereas the Einstein/Schwarzschild metric implies that galaxies whose redshifts exceed unity will *accelerate* instead. The latter approach is a much better match for what is observed than FLRW-based cosmology is, *even with a cosmological constant*.

We should note that the **same** time dilation effects which explain the perihelion shift of Mercury and the gravitational refraction of light ***also** predict* the accelerating expansion of the universe *and the diminution* of that acceleration over time. Reductive assumptions are needed to solve Einstein's equations, which have an endless range of solutions otherwise, but Friedmann's choice of a coordinate condition $g_{00}(x) = 1$ for all x ***rules out*** a fully relativistic cosmological model, because the essentially Newtonian gravity of the FLRW metric form is incompatible with time dilation. However; solutions using the coordinate condition $\det(g_{\mu\nu}(x)) = -1$for all x by Einstein on November 18, 1915, and by Schwarzschild, Dröste, and Hilbert in 1916, preserve Lorentz covariance, ***allowing*** fully relativistic models to be constructed. Our simplified model assumes the universe is a uniform 'dust fluid' and ignores all forces except gravitation, but even our toy model offers useful insights and reproduces the observed character of cosmic expansion well.

The combination of Newtonian gravity with a simple expanding sphere of uniform-density 'dust fluid', wherein dust particles interact with each other only gravitationally, **produces the model cosmology** *described by the red curves* of Figures 1, 2 and 3 (essentially the FLRW version). A signature characteristic of such a Newtonian-gravity cosmology is a singular 'Big Bang' birth of a zero-radius universe at a finite time in the past, as the red curve of Figure 1 shows. After that time the model universe's radius grows with diminishing, ***but unbounded***, radial velocity, as the red curve of Figure 2 shows, in stark disagreement with the speed limit *c* of Lorentzian relativity. The radial acceleration of such a model universe is also unbounded *and always negative*, as the red curve of Figure 3 shows, which of course contradicts the 1998 confirmation of ***positive acceleration*** of the universe’s expansion. We see this as clear evidence that FLRW is **not** a proper formal basis, upon which one can build a physically-realistic cosmology.

On the other hand, the combination of the Einstein/Schwarzschild spherically-symmetric gravitational metric with an expanding sphere of uniform-density ‘dust fluid’, and only gravitational interactions between dust particles, **produces the cosmology** *described by the blue curves* of Figures 1, 2 and 3. The blue curve of Figure 1 shows that this expanding model universe **always** has a finite radius. Since this simplified model universe *has always existed* instead of coming into existence at a finite past ‘Big Bang’ instant, the gross excess of particles relative to antiparticles is not much of an issue. The blue curve of Figure 2 shows that the radial expansion velocity of this model universe *is always less than c*, **in agreement with** Lorentzian (i.e. – Special) relativity. The blue curve of Figure 3 shows that the radial acceleration of this model universe *is always positive*, **in agreement with** the 1998 confirmation of positive acceleration of the universe's expansion. That curve ***peaks sharply*** shortly after this model universe expands to its gravitational or Schwarzschild radius, and then commences *diminishing with time*.

Although our simple model universe has **no** Big Bang, the blue curve of Figure 3 shows that **it experiences a profound behavioral transition** when its size reaches and then grows beyond its Schwarzschild radius. When the cosmos is much smaller than its own Schwarzschild radius, time is slowed to the point of virtual paralysis. When its size almost reaches that radius, the acceleration of its expansion peaks sharply, and thereafter the acceleration of the cosmos' expansion diminishes with its ongoing expansion, **but always remains positive**. This 'toy' model accords better with recent observations than the FLRW + Dark Energy formulation which is currently the Standard Model of astrophysics.

We find it curious that earlier researchers embraced Friedmann's model, without reservations, since it conflicts with the observed perihelion shift of Mercury. But later experiments like Pound-Rebka in 1960 gave further evidence that FLRW is flawed, because it fails to accommodate time dilation. The confirmation of accelerating expansion in 1998 should have ended its use, but researchers did not recognize the error FLRW incorporates. While both the FLRW and the Einstein/Schwarzschild metric are spherically-symmetric and satisfy the Einstein equations, those properties alone don't guarantee that a metric is Lorentz-covariant. The Einstein equation's general coordinate transformation covariance causes it to accommodate *a very wide variety of solutions*. Most researchers do not realize Friedmann's choice for a coordinate condition, $g_{00}(x)=1$ for all x, gives FLRW an essentially Newtonian character, or explain this fact away. To guarantee that our model *is* Lorentz-covariant, and properly incorporates time dilation, we use Einstein's November 18, 1915 coordinate condition $\det(g_{\mu\nu}(x))=-1$ for all x instead.

Once our model cosmos reaches a modest multiple of its Schwarzschild radius it will have decisively sloughed off the paralysis of its former extreme time dilation, but will still be very dense and compact. The universe in such a state would be very appropriate for rapid formation of the large population of extraordinarily compact, bright, extremely hot young galaxies which have recently been revealed by JWST. These plentiful very hot objects in a very compact early universe might conceivably be the source of the now expansion-cooled black-body radiation of the cosmic microwave background we observe.

Our research uses the methodologies of Feynman and Weinberg to derive solutions to Einstein's equations utilizing the forgotten formulations of 1915-16 as a guide. There are built-in problems for anyone trying to create a mathematical description of real-world physics, and we want to avoid past mistakes. Often, higher-order terms needed for physical realism are truncated to have solvable formulas to work with, which is done by making simplifying assumptions. Of course, assumptions made to reduce the range of solutions to a manageable subset can also *filter out interesting behaviors* we need to study! We think this is likely what brought the astrophysics, gravity, and cosmology community to the present situation where our prevailing models fail to entirely explain what we observe.

From Relativity's birth in 1905, while Einstein and others worked to create General Relativity in 2016, and through Friedmann's 1922-24 efforts, working assumptions were made that became a foundation for later works. They agreed with astronomical observations at the time, but with caveats. Einstein's celebrated predictions use a coordinate condition that assures Lorentz covariance (adherence to Special Relativity), which is the basis for our current work. In our research, as detailed in recent papers[11] and in conference presentations[12] at GR24 and the Texas Symposium @ ASU, general covariance emerges in the limit under Lorentz-covariant gravity theory, the reverse of what GR proposes. Unfortunately, important research from the 1915-1916 timeframe was forgotten by history or is misrepresented in modern textbooks. The equation attributed to Schwarzschild does not appear in *his* paper, but is instead the spherically-symmetric formula derived by Dröste and by Hilbert later that year. And *their* work's prediction of a universe with accelerating expansion, in a Lorentz-covariant theory, has been lost to the annals of time. We hope to correct that omission.

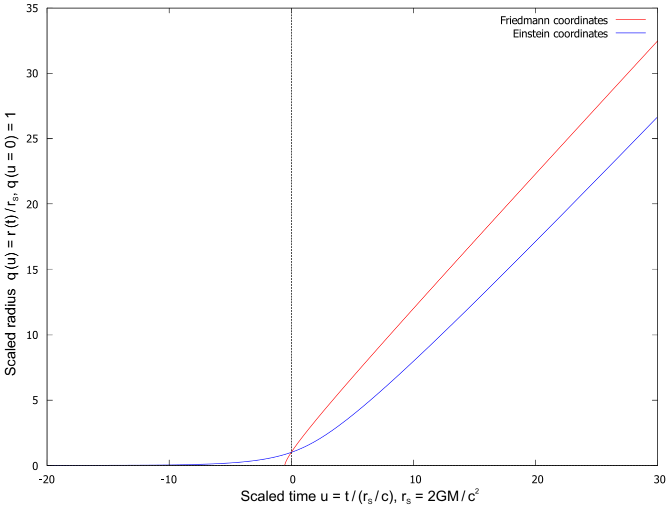

Figure 1 – The expanding universe’s radius versus time

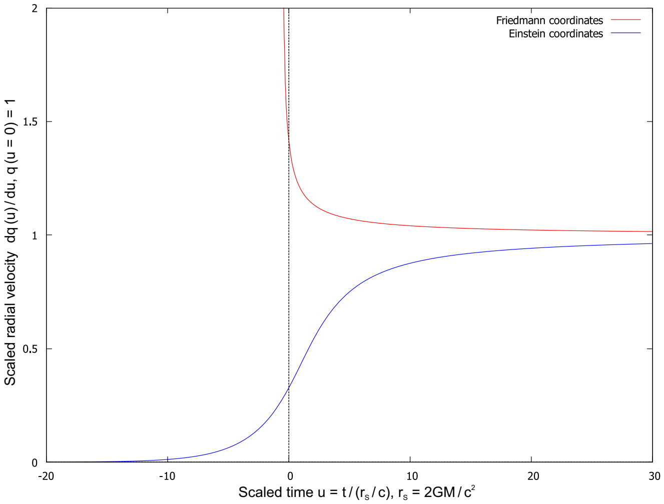

Figure 2 – The expanding universe’s radial velocity versus time

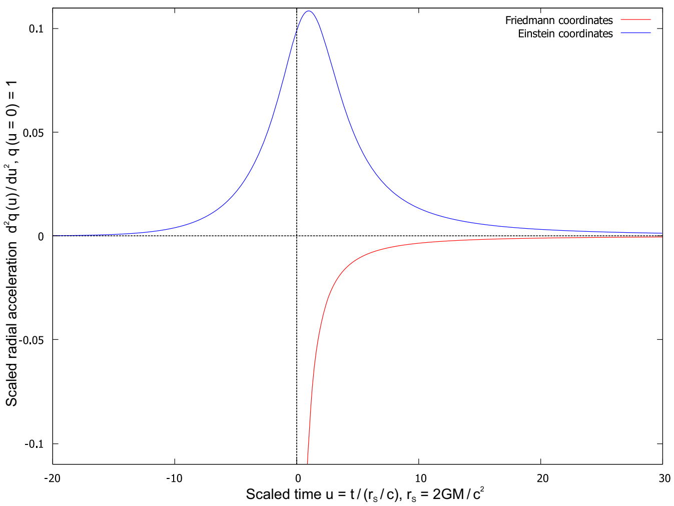

Figure 3 – The expanding universe’s acceleration versus time

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