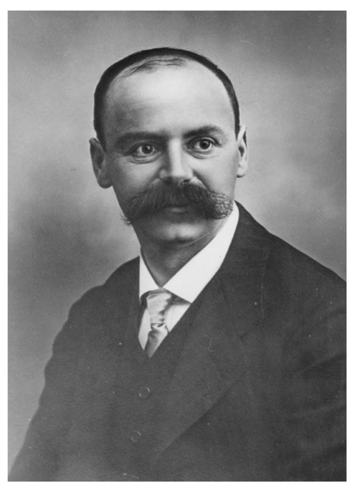
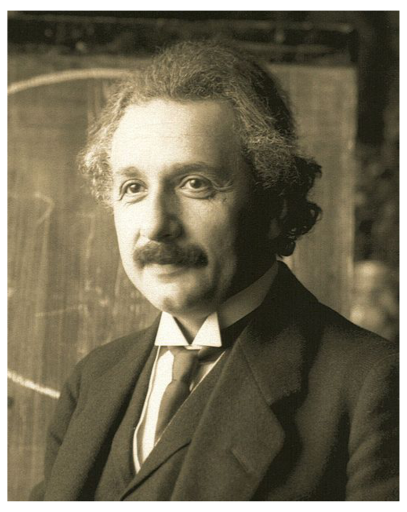
Should Einstein's 1915 Gravitational Coordinates Replace Friedmann's in Cosmology?



Karl Schwarzschild



Albert Einstein

The Historical Basis for our Work

In the period from 1912-1916, Einstein and others explored many ideas to extend concepts from Special Relativity to a broader context, and while some became part of the theory we now know as General Relativity, some good ideas were set aside and later forgotten. Over the next 20 years, various theories of Cosmology were devised, using conventions adopted at that time. The model developed by Friedmann, Lemaître, Robertson, and Walker – describing an expanding universe – appeared to fit all the evidence available and confirm that the conventions adopted with GR were the correct ones to use for Cosmology. But *in that era* it was imagined the velocity of cosmic expansion always remains $\ll c$, so by assuming the universe is isotropic and homogeneous at the largest scales, simplifications *are* proper to make for ease of calculation.

Various attempts were made early on, including the 1917 static universe theory by Einstein, to craft what is now called a steady-state cosmology, but these efforts faded when the evidence favored other possibilities. In 1929, Edwin Hubble confirmed speculations by Lemaître and others that an expanding universe fit the astrophysical evidence better than other models, so the Big Bang cosmology became the predominant model. In addition; scientists canonized a relation called "Hubble's Law" where the recessional velocity of distant galaxies varies with their distance. A 1934 paper by McCrea and Milne appears to legitimize the simplifications made by FLRW as well. However; it *was assumed* the recessional velocities of **all** distant objects remain bounded – *because* an accelerating expansion *would need* an additional force. Ergo; scientists **believed** cosmic expansion was almost linear, but would eventually slow over time.

However in 1979, when negative deceleration parameters began to appear, Raychaudhuri raised concerns that conditions for using the weak-field approximation might break down in Cosmology, making the essentially Newtonian formulas used by FLRW inappropriate. Then in 1998 proof was revealed that the expansion of the universe is ***not*** slowing but accelerating, earning its discoverers, Saul Perlmutter, Brian P. Schmidt, and Adam G. Riess, the Nobel Prize. But though people talked about a Crisis in Cosmology, they failed to see *how deeply* this shook the foundations. It compelled cosmologists to **overturn** invalidated simplifying assumptions and to **reexamine** alternative ideas framed when Relativity was young – that were later discarded, forgotten, or fell into disfavor, when General Relativity was adopted as the final and correct version of Einstein's gravity theory.

We note that while Schwarzschild ***was*** the first to find a spherically-symmetric solution to Einstein's equations; the formula cited in ***virtually all*** textbooks is the solution first found by Dröste and independently by Hilbert. Importantly; **both** published findings in December of 1916, stating that masses with a radial velocity a significant fraction of c away from a massive center see a ***repulsive*** gravitational effect ***from that mass***. Today's latest astrophysical observations affirm this notion, but when it was proposed it appeared unlikely and fell into disfavor. We think this idea deserves a second chance. Utilizing these important forgotten insights, and using Einstein's 1915 coordinate condition – rather than the one used by Friedmann – we derive a Lorentz-covariant upgrade of the Robertson-Walker formula. But even our simplest expanding sphere model nicely reproduces the accelerating expansion that wanes over time which the latest astrophysical observations find.

The Philosophy of Physics and Physical Realism

We must examine the roots of our assumptions about reality and address questions of physical realism to progress in Physics. But ideals of physical realism have fallen by the wayside in modern times. It can be assured by carefully applying simple rules, but modern researchers learn what is true from textbooks, rather than deriving formulas or figuring things out personally, so truths apparent to folks who learned Physics in a prior age with today's knowledge are obscure to modern researchers. Our collaboration is informed by the skillful derivations of Steven K. Kauffmann, a student of Richard Feynman – someone renowned for insisting people figure things out for themselves. Our shared Philosophy of Physics insists on physical-realism and proving things to our own satisfaction, which some modern scientists have not learned to appreciate.

A central question is whether more weight should be given to Math or Physics concerns. There is much debate about Einstein's motivations, when Relativity was being forged, over whether making his Math more consistent or making the Physics phenomenology more true to fact won the day. We tend to favor having things make sense physically, as well as mathematically, *and* be testable. But cosmology is a story of compromises that have hardened into 'facts,' instead of an accumulation of knowledge which got more precise over time, *as is imagined*. Our latest observations ***do not jibe*** with what FLRW or variants that add a cosmological constant or dark energy predict, so it is time to consider other possibilities.

Figure 1 – The universe's radius in the simplest expanding sphere model

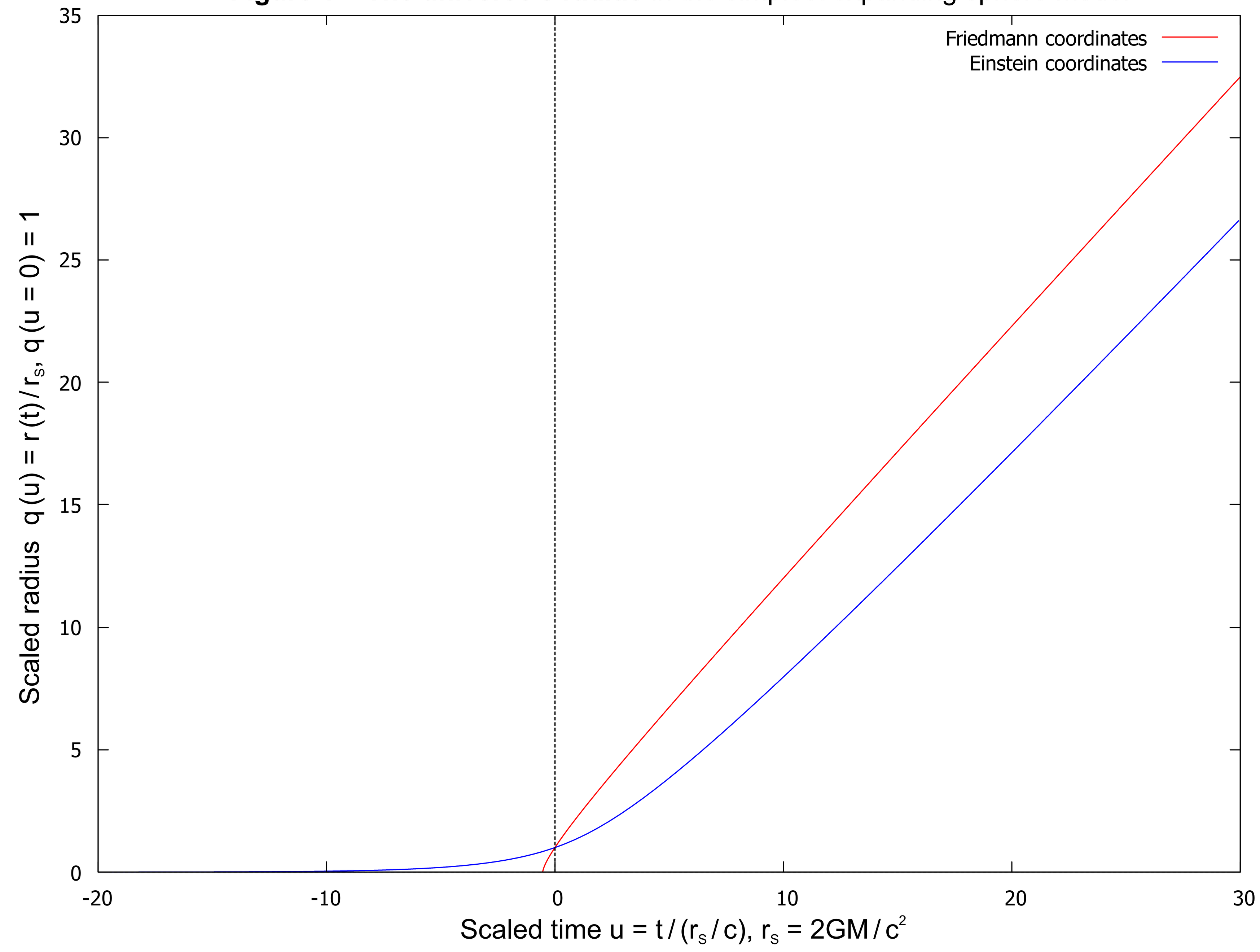


Figure 2 – The universe's radial velocity in the simplest expanding sphere model

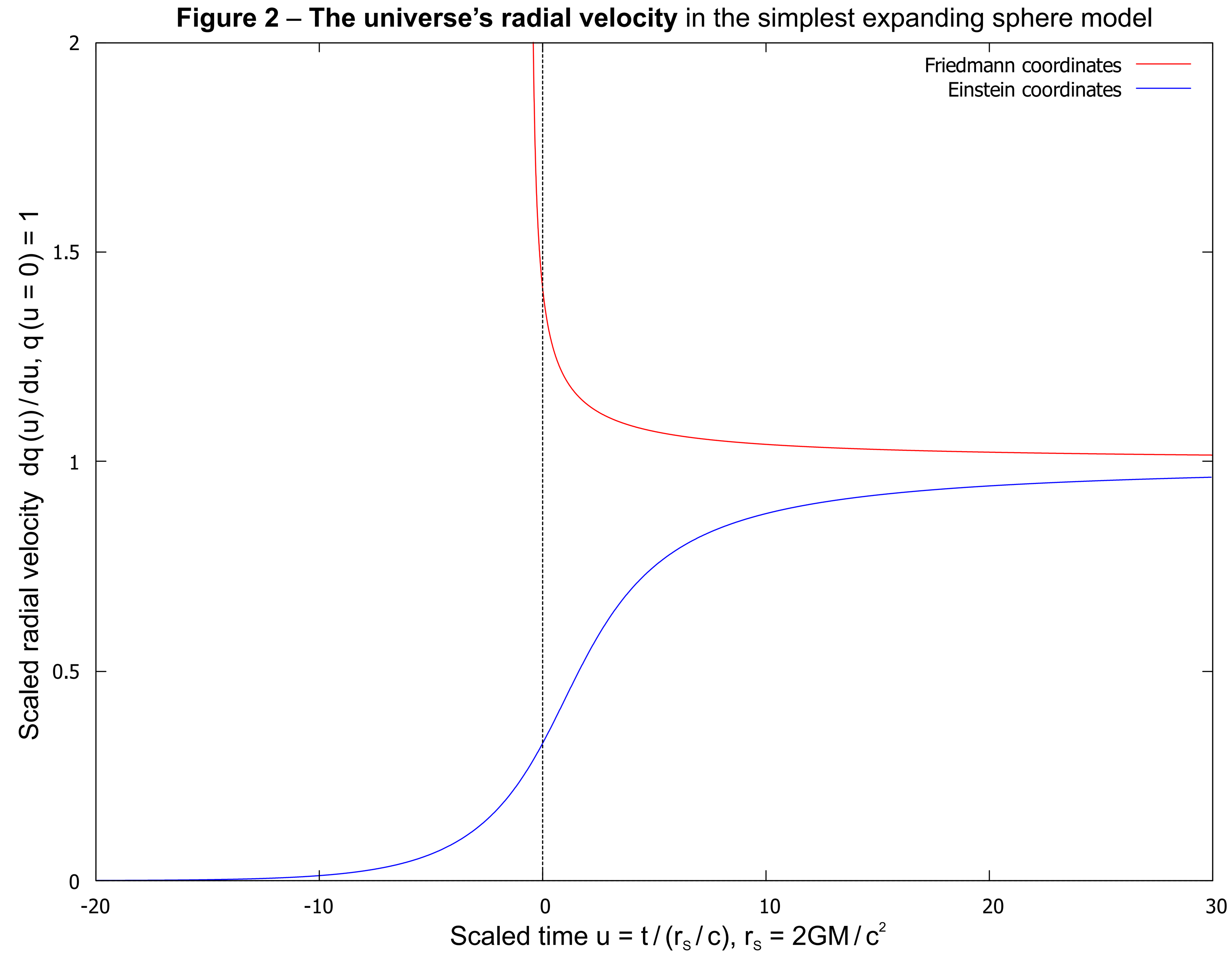
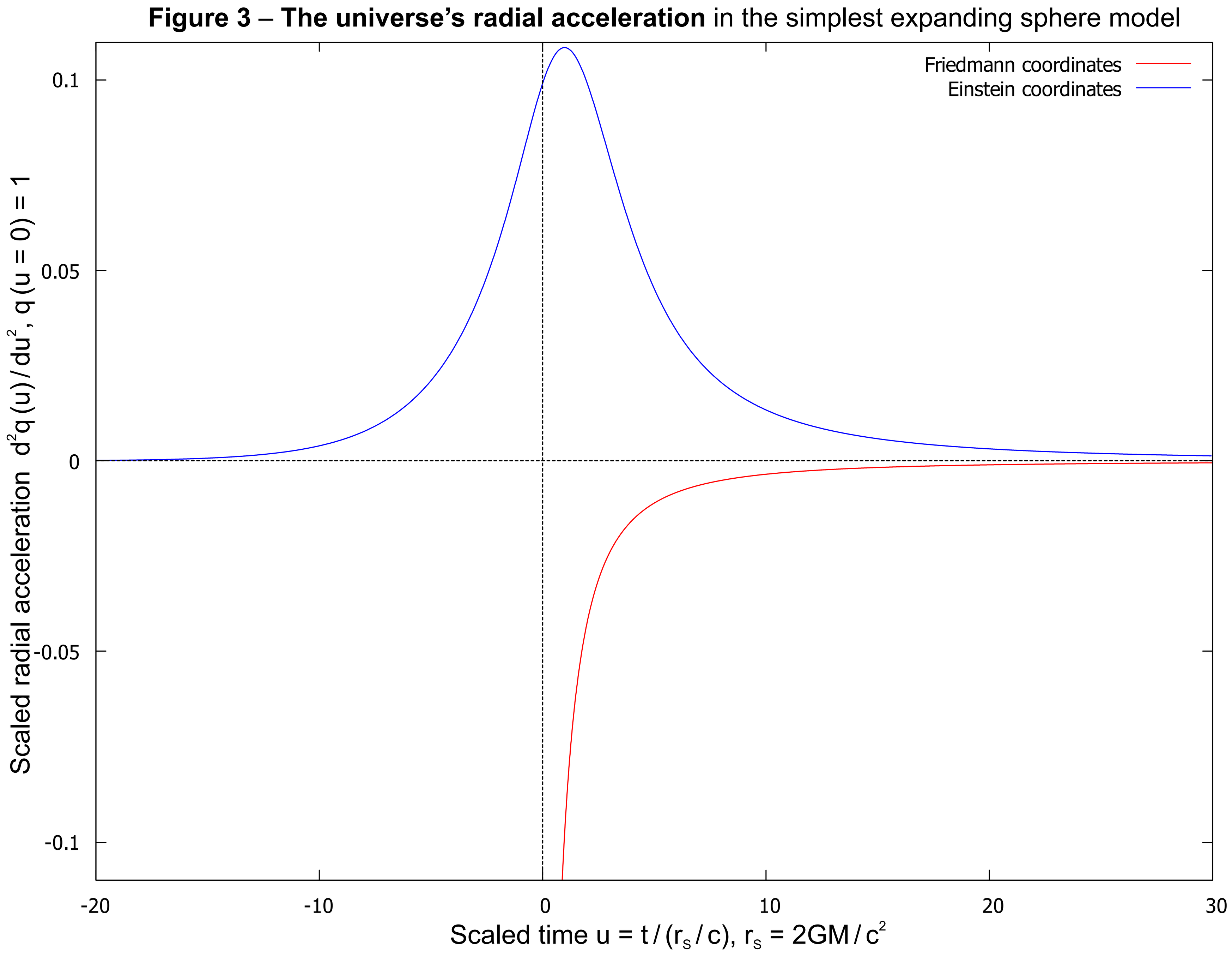


Figure 3 – The universe's radial acceleration in the simplest expanding sphere model



Abstract

The DESI collaboration has found that the acceleration of the universe's expansion weakens with time, and JWST has found a large population of galaxies with $z > 10$. The Friedmann coordinates of the Robertson-Walker metric imply a Big Bang birth of the universe with unbounded expansion speed and perpetual gravitational deceleration of that expansion. The 1998 discovery that the universe's expansion instead accelerates led to trying a cosmological constant in the Einstein equation, but this doesn't accommodate the acceleration's weakening with time found by DESI. Also, the large population of galaxies with $z > 10$ doesn't jibe with the universe's unbounded initial expansion speed. Einstein's observationally-tested 1915 coordinate condition, however, is Lorentz covariant, which bounds all speeds by c. It also implies refractive gravitational slowing of incoming light, so outgoing light is accelerated. Outgoing galaxies whose $z > 0.94$ are similarly accelerated, so the universe's expansion is accelerated, a gravitational effect that inherently weakens as the universe expands. We illustrate the above effects by plotting the time evolution of the simplest expanding-dust-sphere model universe in both Friedmann and Einstein coordinates.

Presenter e-mails: jonathan@jonathandickau.com
and skkauffmann@gmail.com

Johannes Dröste

David Hilbert

The Empirical Evidence for our Work

Recent astrophysical evidence shows that even with the addition of a positive cosmological constant (where Einstein had used a *negative* value), the FLRW model *does not reflect* what we observe, and adding dark energy *does not close* the gap between theory and observations. The observation by the JWST of a large population of galaxies with $z > 10$ and the DESI findings indicating that dark energy *wanes* over time are in conflict with what the concordance or Standard Model of Cosmology predicts we *should* observe. The astrophysics community was already struggling to accommodate a small yet persistent discrepancy between different measurements of the Hubble constant H_0, but these new observations are far worse for cosmology theorists who must now go back to square one. So Cosmology is in a state of flux.

Seeing the discrepancy grow over time, each of us has explored various approaches to closing the gap between theory and observations. Together, we examine using Einstein's 1915 coordinate condition – which made celebrated predictions – in place of Friedmann's, effectively substituting Einstein's 2nd rank tensor $\phi_{\mu\nu}(x)$ for the scalar gravitational potential $\phi(r)$ in Newton's test-body equation, to create a simple Lorentz-covariant expanding sphere model. This upgrade *does* explain or predict what we observe astro-physically. In our model, the universe initially expands more slowly than in FLRW cosmology but its expansion accelerates over time, and that acceleration comes to a peak but then slowly wanes. This is remarkably like what the JWST and DESI teams have just observed! And our result does not need fudge factors for curve fitting – only the appropriate formulas and first principles.

The Theoretical Basis for our Work

The choice of a coordinate condition may seem trivial, but it is not. Friedmann's choice in 1922 to use a coordinate condition $g_{00}(x) = 1$ for all x, has the effect of making the FLRW formulas use Newtonian gravity as a basis – rather than preserving Lorentz-covariance – which ***would*** make FLRW relativistic. Einstein's 1915 coordinate condition $\det(g_{\mu\nu}(x)) = -1$ for all x (which correctly predicts the bending of light and the perihelion shift of Mercury) ***restores*** Lorentz-covariance and relativistic gravity. The resulting upgraded form of the R-W equation generates the **blue** line graphs displayed in **Fig. 1**, **2**, and **3**, for the **radius**, **radial velocity**, and **radial acceleration** of an expanding sphere perfect-fluid model in Einstein's coordinates, where the **red** line graphs it in Friedmann's coordinates. Of course, we are illustrating the simplest fully-relativistic model, and not a fine-tuned theory. But we hope to correct oversights by past researchers who were unmindful of restrictions on the parameter space required to allow simplifications which have become a part of the Standard Model of Cosmology.

Einstein's 1915 work effectively replaces the scalar gravitational potential $\phi(r)$ in the Lagrangian for Newtonian gravity's equation of test body motion with his 2nd rank tensor form $\phi_{\mu\nu}(x) = c^2 (g_{\mu\nu}(x) - \eta_{\mu\nu}) / 2$, allowing us to formulate Lorentz-covariant upgrades of the FLRW formulas. We proceed by analogy with the flux-density of conserved charge $j^\mu(x)$ in Lorentz-covariant EM by using the conserved energy-momentum four-vector as the inherent cause of gravity, with the important difference being that the gravitational field itself carries energy-momentum and is therefore part of its own source. So in the Lorentz-covariant *gravity* theory the cause of local gravitational forces becomes the symmetric second-rank tensor for conserved energy-momentum flux-density $T^{\mu\nu}(x)$. The local gravitational potentials which $T^{\mu\nu}(x)$ produces therefore comprise a symmetric second-rank-tensor entity $\phi_{\mu\nu}(x)$. The upgraded Lagrangian then becomes $L(dx^\mu/d\tau,\ \phi_{\mu\nu}(x)) = (mc^2/2) - (m/2)\eta_{\mu\nu}\ (dx^\mu/d\tau)(dx^\nu/d\tau) - (m/c^2)\phi_{\mu\nu}(x)(dx^\mu/d\tau)(dx^\nu/d\tau)$.

We are pursuing this avenue because that there are gaps, omissions, and errors in most textbooks of the historical development of Einstein's gravity and the theoretical reasons *why* some conventions in GR and Cosmology are used today. FLRW-based models work ***only*** where recessional velocities are non-relativistic, but observations tell a different story. Since Dröste and Hilbert in 1916, there is little discussion of gravitational effects a local mass exerts on distant objects receding at velocities approaching c, but it is time to have that discussion. People are unaware of the *concerns* raised about ideas that have become accepted theory, or *why they matter*. These oversights or omissions are gradually being corrected with the translated texts of historical works becoming available for the first time. But this should be addressed in the domain of theoretical Physics as well, so perhaps some errors of omission, and simplifications adopted before we observed accelerating expansion (and still thought it was impossible), can be corrected at this time.

This poster is based on the paper also entitled "**Should Einstein's 1915 Gravitational Coordinates Replace Friedmann's in Cosmology?**"

by Jonathan J. Dickau,
Steven K. Kauffmann,
and Stanley L. Robertson

at vixra.org/abs/

our **Maxima** code is available on request

Poster design by Jonathan J. Dickau