Article

Not peer-reviewed version

Hubble Tension Resolved by Standard Model Dark Matter

Frank J. Tipler *

Posted Date: 18 March 2026

doi: 10.20944/preprints202603.1471.v1

Keywords: Hubble tension; dark matter; dark energy; Higgs field; Higgs boson cross-section; early universe galaxy formation doi:10.20944/preprints202603.1471.v1

Article

Hubble Tension Resolved by Standard Model Dark Matter

Frank J. Tipler

Department of Mathematics, Tulane University, New Orleans, LA 70118, USA; tipler@tulane.edu

Abstract

If the Standard Model of particle physics is correct, there is only one possible candidate for the dark matter: the oscillation of the Standard Model Higgs field around its universal minimum. It has been known since the 1980's that a rapidly oscillating scalar field with a quadratic potential in a Friedman universe would have matter density $\rho \propto R^{-3}$, the behavior of zero pressure matter. The Standard Model Higgs field would interact only gravitationally and weakly with normal matter, so a rapidly oscillating SM Higgs field would have all the essential properties of the observed Dark Matter. But the SM Higgs field has, in addition to the quadratic term, cubic and quartic terms. This results in a slight modification of $\rho \propto R^{-3}$, and I show that this change resolves the Hubble Tension. I also show how to test this SM solution to the Hubble Tension by astronomical and CERN observations. Finally, I show that this slight modification forces the Dark Matter to have a slight negative pressure, and so early universe galaxy formation will be enhanced above that expected from cold (zero pressure) Dark Matter. The SM naturally couples to general relativity in only one way, and I show this coupling generates an effective cosmological constant, i.e., the Dark Energy.

Keywords: Hubble tension; dark matter; dark energy; Higgs field; Higgs boson cross-section; early universe galaxy formation

PACS: 98.80.Es; 95.35.+d; 95.36.+x; 14.80.Bn

The Standard Model of particle physics (SM) is the experimentally confirmed ([1–3]) theory of all forces and particles except gravity; a theory of all types of matter. It should therefore be able to explain the Dark Matter. And it does: the SM predicts that the Higgs field should oscillate around its global minimum, and the energy of this oscillation has a cosmological evolution exactly the same, $R(t)^{-3}$, as cold Dark Matter. I shall show that when higher order terms in the Higgs field are taken into account, the slight change resolves the Hubble Tension.

All analyses of the Hubble Tension use the Friedman equation:

$$H^2 = \frac{8\pi G}{3}(\rho_{DM} + \rho_{BM} + \rho_{DE}) \tag{1}$$

where ρ_{DM} is the density of the Dark Matter, ρ_{BM} is the density of the baryonic matter, ρ_{DE} is the density of the Dark Energy, and I have dropped the curvature term since it is observationally zero. The local ($z \leq 1$) measurements of ρ_{BM} and ρ_{DE} agree with the PLANCK measurements at $z_* = 1090$, but differ in their values of H^2 at z = 0, which is the Hubble Tension ([4–6]; the CCHP Cepheid distance measurements — but not other distance indicators — [7] confirm the existence of the Tension). The Hubble Tension could result from ρ_{DE} being non-constant, e.g., [8], but these claims require non-standard physics, and have since been ruled out by observation [10]. Therefore, unless the Hubble Tension arises from us being in a supervoid [9], the Tension must come from ρ_{DM}; DESI observations support this at the 2.6σ level, as the DESI investigators point out ([11], p. 24).

Resolving the Hubble Tension via the Dark Matter requires the DM to have a slight negative pressure.

If the relationship between a fluid's pressure p and its mass density ρ is $p = (\gamma - 1)\rho = w\rho$, then it is well-known that the time dependance of ρ is

$$\rho(t) = \rho(t_0)(R(t_0)/R(t))^{3\gamma} \tag{2}$$

so if the Dark Matter has zero pressure, then $\gamma = 1$. But the local measurement of H^2 is greater than the PLANCK measurement projected to z = 0 assuming $\gamma = 1$. The Hubble Tension can be resolved only if $\gamma < 1$, which means that the Dark Matter must necessarily have a slight negative pressure. This follows from the Friedman equation alone, combined with observations, independent of any proposed mechanism for the origin of the negative pressure. A negative pressure means that the pressure tends to bring matter closer rather than push it apart. This in turn means that galaxy formation in the period after re-combination at $z_* = 1090$ will be enhanced above zero pressure (cold) matter.

We can easily calculate the value of γ needed to resolve the Hubble Tension. Let $H_L(t)$ and $H_{PK}(t)$ be the Hubble constants either measured or computed for the small redshift z (Local) or the large redshift z (Planck observatory) respectively. Then, since both agree on the amounts of baryonic matter and Dark Energy, we have from (1)

$$H_L^2(t) - H_{PK}^2(t) = \frac{8\pi G}{3}(\rho_{DML}(t) - \rho_{DMPK}(t)) \tag{3}$$

where $\rho_{DML}(t)$ and $\rho_{DMPK}(t)$ are the density of Dark Matter according to the Local measurements, and according to the Planck measurements respectively. Setting $\rho_{DML}(t_{then}) = \rho_{DMPK}(t_{then}) \equiv \rho_{DM}(t_{then})$ to force the difference in the Hubble constants to be entirely due to $\gamma < 1$ in the period between t_{then}, the time of re-combination, and t_{now}, the time now, we get from (3)

$$H_L^2(t_{now}) - H_{PK}^2(t_{now}) =$$

$$\frac{8\pi G\rho_{DM}(t_{then})}{3}\left(\left[\frac{R(t_{then})}{R(t_{now})}\right]^{3\gamma} - \left[\frac{R(t_{then})}{R(t_{now})}\right]^{3}\right) \tag{4}$$

where the first term appears with the γ because the Local measurement of the Hubble constant reflects the *actual* value of the Dark Matter density, while the second term reflects the *assumed* zero-pressure expansion.

Pulling out the first factor and dividing we get

$$\frac{H_L^2(t_{now}) - H_{PK}^2(t_{now})}{\frac{8\pi G\rho_{DM}(t_{then})}{3}\left[\frac{R(t_{then})}{R(t_{now})}\right]^{3\gamma}} = 1 - \left[\frac{R(t_{then})}{R(t_{now})}\right]^{3(1-\gamma)} \tag{5}$$

Dividing top and bottom of the LHS of (5) by $H_L^2(t_{now})$, we recognize the resulting denominator as the density parameter $\Omega_{DM}(t_{now})$ measured Locally. This gives

$$\left[\frac{R(t_{then})}{R(t_{now})}\right]^{3(1-\gamma)} = 1 - \frac{H_L^2(t_{now}) - H_{PK}^2(t_{now})}{\Omega_{DM}(t_{now})H_L^2(t_{now})} \tag{6}$$

Taking the logarithms of both sides, using the fact that $1 + z_* = R(t_{now})/R(t_{then})$, and a little algebra yields the formula for γ

$$\gamma = 1 + \frac{\log\left[\frac{H_L(t_{now})^2(\Omega_{DM}(t_{now})-1)+H_{PK}(t_{now})^2}{H_L(t_{now})^2\Omega_{DM}(t_{now})}\right]}{3\log(1+z_*)} \tag{7}$$

which, using $\Omega_{DM} = 0.2618$, $H_{PK} = 67.66\,(\mathrm{km/s})/\mathrm{Mpc}$, $H_L = 73.30\,(\mathrm{km/s})/\mathrm{Mpc}$, and $z_* = 1090$ gives

$$\gamma = 0.960 \tag{8}$$

doi:10.20944/preprints202603.1471.v1

I shall now demonstrate the SM gives this value of γ.

The SM Higgs potential, including all classical terms (higher order quantum loop corrections have negligible effect), is

$$V(\phi) = \mu^2\phi^\dagger\phi + \lambda(\phi^\dagger\phi)^2 \equiv V(h) =$$

$$-\frac{1}{8}m_h^2 v^2 + \frac{1}{2}m_h^2 h^2 - \frac{1}{2}\left(\frac{m_h^2}{v}\right)h^3 + \frac{1}{8}\left(\frac{m_h}{v}\right)^2 h^4 \tag{9}$$

where $m_h = 125.10$ GeV is the Higgs boson mass ($\mu^2 = -m_h^2/2$), $v = \frac{1}{\sqrt{\sqrt{2}G_F}} = 246.22$ GeV is the Higgs field vacuum expectation value, and G_F is the Fermi coupling constant ($\lambda = (m_h/\sqrt{2}v)^2$). The second expression for the Higgs potential is the expansion of $V(\phi)$ about its minimum at v, where h is the Higgs field that oscillates. Notice the negative sign in front of the cubic term. To get the minus sign, I have set $\phi^\dagger\phi = (v-h)^2/2$, rather than the standard $\phi^\dagger\phi = (v+h)^2/2$. The sign is arbitrary theoretically; no reason to choose the $+h$ rather than the $-h$. This change gives a minus sign between the mass terms and the fermion-Higgs boson tree level coupling terms; an unobservable phase shift. The cosmological consequences of the choice are enormous. Were the minus sign replaced with the plus sign, we would necessarily have $\gamma > 1$. We shall see that the minus sign will force γ to be slightly less than 1. Were the cubic and quartic terms missing, the Higgs oscillation would be harmonic, and $\gamma = 1$ exactly. Tommaso Dorigo has pointed out to me that $-h$ changes the κ_λ parameter in the two Higgs production cross section (Figure 1 in [12]) from $\kappa_\lambda = 1$ to $\kappa_\lambda = -1$ since it changes the quartic term. Current observation gives $\kappa_\lambda > -1.25$ (Figure 6 in [12]), So this theory of the DM can be tested by CERN simply by more precise observations of $\sigma(pp \to HH)$. Cosmology requires $\kappa_\lambda = -1$.

Turner [18] has shown that if the Higgs field oscillation frequency $\omega = m_h = 1.90 \times 10^{26}\text{sec}^{-1} >> H$, where H is the Hubble constant (this inequality holds both now ($H(t_{now}) = 2 \times 10^{-18}$ sec^{-1}) and at redshift $z_* = 1090$, the CBR decoupling time, but *not* in the extremely early universe), then

$$\gamma = 2\frac{\int_0^{h_{max}}(1 - V(h)/V_{max})^{1/2}\,dh}{\int_0^{h_{max}}(1 - V(h)/V_{max})^{-1/2}\,dh} \tag{10}$$

where h_{max} is the maximum value of the Higgs field during the oscillation, and V_{max} is the maximum value of the Higgs potential in the oscillation. Equation (10) assumes that $V(0) = 0$, which is to say, the potential $V(h)$ must be expanded around a minimum of zero; the first term in (9) which is in standard particle physics is renomalized to zero, must be so renormalized, as I shall discuss below.

The denominator integral is not defined for $h_{max} = v$, and the approximation (10) would break down for $h_{max} = v$, so $h_{max} < v$. Using all terms (except the constant term) in (9) and $h_{max} = v/6$ gives $\gamma = 0.961$ and thus resolves the Hubble Tension.

This resolution of the Hubble Tension can be checked observationally by measuring the Hubble constant at redshifts 10 and 100, and comparing the Hubble constant predicted by a dark matter evolution given by (8).

The above argument assumes, as I mentioned, that the constant term $-m_h^2 v^2/8 = -2.6 \times 10^{25}$ gm/cm^3 is absent. If it is not, then it would act as a negative cosmological constant. I have shown [14] that all globally hyperbolic universes (universes that obey unitarity — conservation of information), be they open, closed or flat, with a negative cosmological constant must necessarily re-collapse to a final singularity. For a radiation-dominated Friedman universe, the time between the initial and final singularities is $\sqrt{3\pi/32G|\rho_\Lambda|} = 0.4$ nanoseconds for $\rho_\Lambda = -m_h^2 v^2/8$. The obvious absence of such an enormous cosmological constant is well-known, and the standard resolution is to renormalize the Higgs vacuum energy, which is what I shall do here.

I showed in [15] that the SM automatically solves the baryogenesis problem, because quantum field theory (QFT) requires the universe to begin with the only field present being a self-dual $SU(2)_L$ field at zero temperature. I also showed that this field necessarily has a Planck spectral distribution (with 1/R(t) in place of T) if the geometry is FRW, as QFT forces the universe at the singularity to be (thus the isotropy and homogeneity problems are solved with no need for inflation). SM baryogenesis works by vacuum tunneling, conserving B -L so the universe has an equal number of baryons and leptons (and net zero electric charge), and this vacuum tunneling increases the effective density of the vacuum. It has been known for more that half a century ([20], p. 410) that the energy of the vacuum behaves exactly like a cosmological constant. That is, the creation of matter in the early universe generated a very small positive cosmological constant, and this cosmological constant is the Dark Energy that is currently causing the universe to accelerate its expansion. This Dark Energy would be independent of time so long as baryogenesis were not reversed. (Note that this vacuum energy increase is distinct from the mass density of the baryons, which decreases with the expansion of the universe.) This Dark Energy would also be independent of space, since the baryogenesis mechanism described in [15] is a quantum mechanically globally coherent process; creation (or annihilation) 0f a single proton would slightly raise (or lower) the Dark Energy globally.

There are three reasons why the Higgs oscillation mechanism was not proposed as the Dark Matter in the 1980s. First, the Higgs mass was not known until 2012, so the parameters μ^2 and λ could not be computed. Second, it was generally believed that the oscillation would rapidly decay due to particle emission, via coupling of the Higgs field with leptons. But both today and at $z_* = 1090$, the energy density of the Higgs field is too small to be transferred even to a neutrino-anti-neutrino pair. Finally, it was believed that thermodynamic equilibrium was achieved in the very early universe, and this damped out the Higgs field oscillation. But Sakharov showed that thermodynamic equilibrium would make the observed baryon asymmetry impossible by any mechanism. If the beginning field $SU(2)_L$ persisted to the present, then (when the Higgs symmetry breaking is taken into account), this field would be the CBR, and its particles would act like ordinary photons, except these pseudo-photons would not couple to right-handed leptons or quarks. This prediction of the pseudo-photon nature of the CBR has now been confirmed by observation [13,17,19]. So the Higgs field oscillation has not been damped.

Firmly established physics, the SM, tells us what the Dark Energy is, what the Dark Matter is, and it resolves the Hubble Tension.

ACKNOLEDGEMENTS: I am grateful to Tommaso Dorigo, Daniel Merdes and Bruce Partridge for their comments on an earlier draft of this paper.

References

1. Tommaso Dorigo 2024 "News Of The Demise Of The Standard Model Were Exaggerated," *Science Blog 2.0* (July 22, 2024) (Muon anomaly disappears from theory).
2. D. Castelvecchi 2023 "Dreams of New Physics Fade with Latest Muon Magnetism Result," *Nature* **620** (17 August 2023), 473–474..
3. E. Gibney 2024 "The Standard Model is not Dead," *Nature* doi: https://doi.org/10.1038/d41586-024-03042-9 (CERN measurement of W mass confirms SM).
4. A. Riess *et al* 2022 "A Comprehensive Measurement of the Local Value of the Hubble Constant with 1 km/s/Mpc Uncertainty from the Hubble Space Telescope and the SH0ES Team," *Ap JL* **934** L7.
5. A. Riess *et al* 2024 "JWST Observations Reject Unrecognized Crowding of Cepheid Photometry as an Explanation for the Hubble Tension at 8σ Conf!dence," *ApJL* **962** L17.
6. A. Alexie Leauthaud and A. Riess 2025 "Looking Beyond Lambda," *Nature Astronomy* **9** 1123–1128.
7. W. L. Freedman *et al* 2024 "Status Report on the CCHP." arXiv:2408.06152v1 [astro-ph].
8. M. Kamiokowski and A. Riess 2022 "The Hubble Tension and Early Dark Energy," arXiv:2211.04492.
9. Sergij Mazurenko *et al* 2024 "A Simultaneous Solution to the Hubble Tension and Observed Bulk Flow Within 250 h^{-1} Mpc." *MMRAS* **527** 4388–4396.
10. Evan McDonough *et al* 2023 "Observational Constraints on Early Universe Dark Energy," arXiv:2310.19899v1.
11. A. Adams *et al* 2024 "DESI 2024 VI: Cosmological Constraints from the Measurements of Baryon Acoustic Oscillations." arXiv:2402.03002v2, DESI II 2503.14738v1.
12. The CMS Collaboration 2022 "A Portrait of the Higgs Boson by the CMS Experiment Ten Years After the Discovery." *Nature* **607** 60–68.

13. D. W. Piasecki 2022 “Northern Hemisphere UHECR data further supports CMBR photons with weak U(1) component.” *Journal of High Energy Astrophysics* **35** 176–184.
14. F. J. Tipler 1976 “Singularities in Universes with Negative Cosmological Constant,” *ApJ* **209** 12–15.
15. F. J. Tipler 2005 “The Structure of the World From Pure Numbers,” *Rep. Prog. Phys.* **68** 897–964.
16. F. J. Tipler, J. Graber, M. McGinley, J. Nichols-Barrer, and C. Staecker 2007 “Closed Universes With Black Holes But No Event Horizons As a Solution to the Black Hole Information Problem *MMRAS* **379** 629–640.
17. F. J. Tipler and D. W. Piasecki 2018 “Identifying the Unidentified Auger UHE Cosmic Rays with the Help of the Standard Model of Particle Physics,” ArXiv 1809.08492v1 [astro-ph.HE].
18. M. S. Turner 1983 “Coherent Scalar-field Oscillations in an Expanding Universe.” *Phys. Rev. D* **28** 1243–1247.
19. F. J. Tipler 2024. ‘”Section 3: Experimental Evidence that the Baryogenesis Mechanism Is Standard Model Physics.” *J. Br. Interplanet. Soc.* **77** (# 10) 345–354.
20. C. W. Misner, K. S. Thorne, and J. A. Wheeler 1973 *Gravitation* Freeman, San Francisso.