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The Neutrino Paradox: Mathematical Inconsistency of Hot Big Bang Thermodynamics A Falsification Test for the Standard Cosmological Model

Sergiu Vasili Lazarev

NMSI Research Institute, Romania

***Corresponding author:** Sergiu Vasili Lazarev, NMSI Research Institute, Romania.

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Abstract

The standard Hot Big Bang (HBB) model predicts thermal production of relic neutrinos with number density n_ν ≈ 336 cm⁻³ at decoupling temperature T_dec ≈ 1 MeV. If neutrino energy does not undergo "cooling" (via metric redshift or other mechanism), the current mean energy would be ⟨E_ν⟩ ≈ 3.8 MeV, yielding energy density ρ_ν ≈ 1.3×10⁹ eV·cm⁻³, approximately 2.5×10⁵ times larger than the measured critical density ρ_crit ≈ 5×10³ eV·cm⁻³. This pure mathematical inconsistency requires either abandonment of thermal HBB, or acceptance of universal metric redshift E ∝ 1/a. Neutrino observations from supernova SN1987A (z_cosmological ≈ 10⁻⁵) cannot discriminate redshift at this level but provide upper limits (z_ν < 10⁻⁴). We propose a multi-method experimental program to test redshift universality: (1) re-analyzed SN1987A data, (2) future supernovae at z > 0.01, (3) Diffuse Supernova Neutrino Background (DSNB), (4) direct Cosmic Neutrino Background (CvB) detection via tritium capture. A "golden event" (core-collapse supernova at z > 0.01 with >500 detected neutrinos) expected in 2027-2035 will provide definitive discrimination: if |z_ν - z_γ| > 3σ, ΛCDM is falsified and alternative frameworks (NMSI) become necessary.

Keywords: Relic Neutrinos, Big Bang, Falsification, λcdm, Critical Density, Cosmological Test, Hyper-Kamiokande, Snews, Redshift Universality.

Introduction

A. Context of the Problem

The standard cosmological model (ΛCDM) is based on the Hot Big Bang (HBB),
characterized by:

- Initially dense and hot universe
- Metric expansion: scale factor a(t) increases over time
- Temperature decreases proportionally: $T \propto 1/a$
- Relativistic particles (photons, neutrinos) undergo metric redshift: $E \propto 1/a$ Consequences for neutrinos within ΛCDM:
- Decoupling at $t \approx 1$ second, temperature $T_{dec} \approx 1$ MeV
- Number density conserved (from entropy): $n_\nu \approx 336$ cm^{-3}
- Present temperature: $T_{\nu,0} \approx 1.95$ K $\approx 1.68\times10^{-4}$ eV
- Present mean energy: $\langle E_{\nu,0}\rangle \approx 5\times10^{-4}$ eV

The central problem:

Metric redshift $E \propto 1/a$ is NECESSARY for the energetic consistency of HBB. Without it, HBB produces a neutrino background with catastrophic energy density, incompatible with fundamental cosmological observations.

B. Originality of the Approach

Unlike previous attacks on ΛCDM (H_0 tension, horizon problem, BBN abundances), our attack is:

Purely Mathematical: - Does not depend on specific cosmological interpretations - Does not depend on complex models with free parameters - Does not depend on distance ladder calibration

Reductio Ad Absurdum

We demonstrate that the hypothesis system {thermal HBB + entropy conservation + energy without cooling} is internally inconsistent, independent of any particular cosmological framework.

Uniqueness of the Attack

Unlike the H_0 tension (which can be resolved through recalibration) or the horizon problem (which requires inflation but does not logically contradict ΛCDM), the neutrino inconsistency is INTERNAL and cannot be "repaired" by adding additional free parameters. Either you abandon thermal HBB, or you accept metric redshift — there is no third option.

Mathematical Demonstration (Reductio Ad Absurdum)
C. The Axioms
Axiom A1 (thermal HBB + entropy conservation)
$n\_\nu = 336\ cm^{-3}$

Source: Standard calculation from the thermal epoch, independent of redshift. Kolb & Turner formula [1]:
$n\_\nu = (3/11) \cdot (2\zeta(3)/\pi^2) \cdot (T\_\gamma,0)^3 \approx 56$ neutrinos/cm³ per flavor
Total (3 flavors × 2 for neutrinos/antineutrinos): $336\ cm^{-3}$
Axiom A2 (Energy Without Mechanical Cooling) ∝E_ν∝ = 3.8 MeV = 3.8 × 10⁶ eV
Source: Thermal Fermi-Dirac distribution at decoupling temperature $T\_dec \approx 1$ MeV:
$\langle E\rangle = \int E \cdot f\_FD(E,T)\, dE / \int f\_FD(E,T)\, dE \approx 3.15\ kT \approx 3.8$ MeV

Testable hypothesis: Neutrino energy does not change after production. No metric redshift, no other cooling mechanism.

Axiom A3 (Observational Critical Density)
$\rho\_crit = 5 \times 10^3\ eV\cdot cm^{-3}$
Source: Independent cosmological measurements (CMB [2], SNIa [3], BAO [4]):
$\rho\_crit = 3H_0^2/(8\pi G) \approx 10^{-29}\ g\cdot cm^{-3}$
Conversion to energy units ($1\ eV/c^2 \approx 1.78\times10^{-33}$ g):
$\rho\_crit \approx 5\times10^3\ eV\cdot cm^{-3}$

D.The Deduction
Step 1. Energy Density of the Neutrino Background
$\rho\_\nu = n\_\nu \cdot \langle E\_\nu\rangle$
$\rho\_\nu = 336\ cm^{-3} \cdot 3.8\times10^6\ eV$
$\rho\_\nu = 1.2768 \times 10^9\ eV\cdot cm^{-3}$

Step 2. Ratio to Critical Density
$\Omega\_\nu = \rho\_\nu / \rho\_crit$
$\Omega\_\nu = (1.2768\times10^9\ eV\cdot cm^{-3}) / (5\times10^3\ eV\cdot cm^{-3})$
$\Omega\_\nu = 2.5536 \times 10^5$

Step 3. The Contradiction
Minimal observational constraint from CMB geometry and large-scale structure dynamics:
$\Omega\_total \approx 1$
For consistency, any individual component must satisfy:
$\Omega\_i \leq \Omega\_total$
Applied to neutrinos:
$\Omega\_\nu \leq 1$
From our deduction:
$\Omega\_\nu = 2.55 \times 10^5$
This yields the relation that must simultaneously be true:
$1.2768 \times 10^9\ eV\cdot cm^{-3} \leq 5 \times 10^3\ eV\cdot cm^{-3}$
This is equivalent to:
$2.55 \times 10^5 \leq 1$
This is FALSE.

Contradiction ∝
E. Logical Consequence
From the inconsistency of the system {A1, A2, A3}, by reductio ad absurdum:¬(A1 ∝ A2 ∝ A3)
By De Morgan's law:
¬A1 ∝ ¬A2 ∝ ¬A3

Interpretation
At least one of the three axioms is FALSE. There is no fourth option.

Any attempt at "rescue" through introduction of a new parameter (example: "neutrinos oscillate into sterile states that then disappear") is ad-hoc and requires independent experimental evidence, which currently does not exist [1- 24].

Analysis of Options
Option 1: ¬A1 (number density is not $336\ cm^{-3}$)
Implication: Thermal Hot Big Bang did not exist in standard form, OR entropy was not conserved through an unknown mechanism.

Required Reduction Factor
$n\_\nu,consistent = \rho\_crit / \langle E\rangle = (5\times10^3\ eV\cdot cm^{-3}) / (3.8\times10^6\ eV) \approx 1.3 \times 10^{-3}\ cm^{-3}$ Reduction factor: $336 / (1.3\times10^{-3}) \approx 2.6 \times 10^5$

Counter-Argument
Requires disappearance of 99.9996% of neutrinos through an ad-hoc mechanism. No known mechanism in particle physics allows selective disappearance of neutrinos while preserving CMB photons (which have comparable number density, $n\_\gamma \approx 411\ cm^{-3}$).

Option 2: ¬A2 (mean energy is not 3.8 MeV)
Implication: There exists an energy cooling mechanism (metric redshift or something else).

Required Reduction Factor
$\langle E\rangle$ consistent $= \rho\_crit / n\_\nu = (5\times10^3\ eV\cdot cm^{-3}) / (336\ cm^{-3}) \approx 15$ eV Reduction factor: $(3.8\times10^6\ eV) / (15\ eV) \approx 2.5 \times 10^5$

Important: Standard ΛCDM requires a cooling factor of ~6×10^9 (down to $T\_\nu \approx 1.95\ K \approx 1.68\times10^{-4}$ eV). This represents an "over-correction" by factor ~10^4 compared to what is strictly necessary for energetic consistency. For $\rho\_\nu \approx \rho\_crit$, it would be sufficient for neutrinos to be cooled only to ~15 eV, NOT to 10^{-4} eV.

Testability
Metric redshift $E \propto 1/a$ must be UNIVERSAL (applicable to all relativistic particles). Universality can be experimentally tested by comparing z_ν vs z_γ for the same astrophysical source.

Option 3: ¬A3 (critical density is not $5\times10^3\ eV\cdot cm^{-3}$)

Implication: Fundamental cosmological measurements are erroneous by over 5 orders of magnitude.

Required Increase Factor
$\rho\_crit,consistent = n\_\nu \cdot \langle E\_\nu\rangle = 1.2768\times10^9\ eV\cdot cm^{-3}$

Increase factor: $(1.2768\times10^9) / (5\times10^3) \approx 2.6 \times 10^5$

Counter-Argument
Critical density is measured independently through multiple methods (CMB, SNIa, BAO, weak gravitational lensing) with

excellent consistency between them. An increase by factor ~10^5 would require $H_0 \approx 7000$ km/s/Mpc (versus ~70 km/s/Mpc measured), incompatible with any local observation (Cepheids, SNIa, direct geometric measurements via parallax).

Probability Hierarchy
On criteria of parsimony (Occam's Razor) and independent testability:
Option 1 (¬A1): Very improbable — requires ad-hoc mechanism without independent evidence
Option 3 (¬A3): Extremely improbable — directly contradicted by 4+ independent methods
Option 2 (¬A2): Most plausible — if we accept the existence of a cooling mechanism
Conclusion: Saving HBB OBLIGATORILY requires an energy cooling mechanism (metric
redshift or something else). Standard ΛCDM offers metric redshift $E \propto 1/a$, but this must be experimentally tested through direct measurement of z_ν.

Direct Detectability (Observational Bonus)
If {A1, A2} are simultaneously true, a catastrophic detection rate results in current detectors.

Isotropic Flux
$\Phi_\nu = n_\nu \cdot c = 336\ \text{cm}^{-3} \cdot 3\times10^{10}\ \text{cm}\cdot\text{s}^{-1} \approx 1.0\times10^{13}\ \text{cm}^{-2}\cdot\text{s}^{-1}$
Cross-section (inverse beta decay, $\bar{\nu}_e + p \to e^+ + n$ at E=3.8 MeV) [5]: $\sigma(E) \approx 10^{-43}\ \text{cm}^2 \cdot (E/\text{MeV})^2$
$\sigma(3.8\ \text{MeV}) \approx 1.4\times10^{-42}\ \text{cm}^2$

Rate in Super-Kamiokande (50 kt water, $N_p \approx 10^{33}$ free protons) [6]:
$R = \Phi_\nu \cdot \sigma \cdot N_p \approx (1.0\times10^{13}) \cdot (1.4\times10^{-42}) \cdot (10^{33})\ \text{s}^{-1}$ $R \approx 1.4\times10^4\ \text{s}^{-1} \approx 1.2\times10^9$ events/day

Comparison with Observations
Super-K observes ~10 events/day (solar + atmospheric + reactor neutrinos).

Ratio: $(1.2\times10^9) / 10 \approx 1.2\times10^8$

Conclusion
The MeV background would completely dominate any detector by factor ~10^8. Nothing of this kind is observed. ⇒ The combination {A1, A2} cannot coexist with observational reality.

Experimental Testing of Redshift Universality
F. The Central Problem
ΛCDM Maintains
Metric redshift is UNIVERSAL for all relativistic particles:
$z_\nu = z_\gamma$ for any astrophysical source
Alternative (NMSI — New Subquantum Informational Mechanics):
Redshift is an INTERACTIONAL effect (medium-dependent):
$z_\gamma \neq z_\nu$ (photons interact with plasma/PON-G, neutrinos do not)

Crucial Test
Simultaneous measurement of z_ν and z_γ for the same astrophysical source.

G. Experimental Methodology
Method 1: Re-analysis of SN1987A
Existing data [7]: - 24 neutrinos detected (Kamiokande-II: 11, IMB: 8, Baksan: 5) - Energy: 7.5-40 MeV - Distance: D ≈ 50 kpc (Large Magellanic Cloud) - Burst duration: ~12 seconds

Photonic Redshift (From Hubble Law)
$z_\gamma = H_0 \cdot D / c \approx (70\ \text{km/s/Mpc}) \cdot (0.05\ \text{Mpc}) / (3\times10^5\ \text{km/s}) \approx 5\times10^{-6}$ Expected

Neutrino Redshift (ΛCDM)
$z_\nu = z_\gamma \approx 5\times10^{-6}$

Energy Shift
$\Delta E = z \cdot E \approx (5\times10^{-6}) \cdot (10\ \text{MeV}) \approx 50$ eV

Direct Testability
Kamiokande energy resolution: $\sigma_E \approx 20\%$ at 10 MeV ≈ 2 MeV

Statistics: $N = 24 \Rightarrow \sigma_{mean} \approx \sigma_E / \sqrt{N} \approx 400$ keV
A 50 eV shift is **BELOW THRESHOLD** for direct detection (factor 8000 smaller than resolution).
Alternative test — temporal distribution E(t):
Proto-neutron-star cools over time: T(t) decreases ⇒ ⟨E(t)⟩ decreases monotonically
If redshift $z_\nu = 5\times10^{-6}$ exists, the observed dE/dt slope would be reduced by factor $(1+z_\nu)$.

Linear fit: $E_{obs}(t) = E_0 - \beta\cdot t$

Comparison: β_{obs} vs $\beta_{prediction}$ (from proto-neutron-star hydrodynamic models)

Current Result
Data compatible with both scenarios ($z_\nu \approx 0$ OR $z_\nu \approx 5\times10^{-6}$), but provides upper limit:
$z_\nu < 10^{-4}$

Method 2: Future Supernova at z > 0.01 (GOLDEN EVENT)
Motivation
For z > 0.01, energy shift becomes > 1% (detectable with large statistics).

Infrastructure [8]: - IceCube-Gen2 (>10 km³ effective volume) - Hyper-Kamiokande (260 kt water) - JUNO (20 kt, energy resolution 3%/√E) - DUNE (40 kt far detector) - SNEWS 2.0 (automatic alert, latency <1 second)
Protocol:
1. Neutrino detection: N > 500 events (for SN at z = 0.01-0.05)
2. Automatic alert: SNEWS 2.0 → optical/UV telescopes
3. Rapid spectroscopy: z_γ from emission lines (H-α, O III, Fe) in <1 hour
4. Neutrino spectrum analysis:
- Temporal binning (10 intervals of ~1-2s)
- Fermi-Dirac fit on each bin: dN/dE □ $E^2 / (\exp((E-\mu)/kT) + 1)$
- Extract $T_{apparent}(t)$
5. Comparison with hydrodynamic models:
- $T_{model}(t)$ from proto-neutron-star cooling simulations
- If $z_\nu > 0$: $T_{apparent} = T_{model} / (1+z_\nu)$
6. Extract z_ν: from global fit on $T_{apparent}(t)$ vs $T_{model}(t)$

Discrimination
ΛCDM: $z\_\nu = z\_\gamma$ (within 3σ)

NMSI: $z\_\nu << z\_\gamma$ (significant difference >3σ)
Expected Significance
For $z\_\gamma = 0.01$, shift = Δ(kT) ≈ 30 keV (at T ~ 3 MeV)
With N = 500, resolution on T: $\sigma\_T \approx (3\% \cdot 3 \text{ MeV}) / \sqrt{500} \approx 4$ keV
⇒ Significance: (30 keV) / (4 keV) ≈ 7.5σ (clear detection)

Golden Event Probability
Core-collapse SN rate in Hyper-K volume (z < 0.05): ~3% per year Cumulative probability 2027-2035 (8 years): ~30%

Method 3: Diffuse Supernova Neutrino Background (DSNB) Concept
Integral over the entire history of star formation [9]:
$\Phi\_DSNB(E) = \int dz \cdot R\_SN(z) \cdot (dN/dE\_em) \cdot (1+z)^\alpha$
where α depends on cosmology: - ΛCDM: α = -1 (standard kernel from metric redshift) -
NMSI (no redshift): α = 0 (no kernel)

Spectral Shape
ΛCDM → "excess" at low energies (contributions from high z are redshifted) NMSI → "flatter" spectrum (no systematic redshift)

Test
Fit on detected DSNB spectrum with two models (with/without kernel).
$\Delta\chi^2 > 25$ (5σ) → clear discrimination

Current Status
Super-K [10]: Upper limits $\Phi\_DSNB < 3 \text{ cm}^{-2}\cdot\text{s}^{-1}$ (8-30 MeV)
Hyper-K + JUNO (2030+): Sufficient sensitivity for first detection

Method 4: Cosmic Neutrino Background (CνB) — Direct Detection
Concept [11]
Capture on tritium: $^3H + \nu\_e \rightarrow {}^3He + e^-$

Kinematic threshold: E_threshold ≈ 2 eV (or lower for small masses)

Predictions
ΛCDM: $T\_\nu \approx 1.95$ K ⇒ ⟨E_ν⟩ ≈ 5×10^{-4} eV ⇒ extremely difficult detection (rate ~few events/year per 100g tritium)

NMSI (no redshift): $T\_\nu \approx$ MeV ⇒ would have been MASSIVELY detected in any neutrino experiment (rate ~10^9 events/day)
Status

PTOLEMY (prototype): ~100g tritium, target detection 2030+
If MeV CνB exists, it is IMPOSSIBLE not to have already seen it in Super-K, Borexino, etc.

Non-detection of MeV background supports either: - ΛCDM (CνB is cold, sub-meV, not yet detectable) - NMSI (CνB does not exist, because thermal HBB did not exist)

H. Comparative Predictions Table

Observable	ΛCDM (expansion)	NMSI (no exp.)	Current Status
ρ_ν (MeV background)	Impossible (cooled to meV)	1.3×10^9 eV/cm³ (catastrophic)	NOT detected ✅ Excludes {A1,A2}
z_ν (SN1987A) z_ν (SN at z=0.01)	~5×10^{-6} (below threshold) = z_γ = 0.01	≈ 0 << z_γ (z_ν ≈ 0)	Inconclusive (below resolution) Awaiting (golden event)
DSNB spectrum	Kernel $(1+z)^{-1}$ (low excess)	No kernel (flat)	Super-K limits, Hyper-K 2030+
Direct CνB (meV) Ω_ν (current)	Detectable (difficult, 2030+) < 0.01 (from CMB+LSS)	Does NOT exist (or MeV = seen) ~10^5 (absurd) if {A1,A2}	NOT detected ✅ Consistent < 0.01 (CMB+LSS) ✅ Requires cooling

Conclusions

1. Pure mathematical demonstration:
Thermal Hot Big Bang + entropy conservation + energy without cooling ⇒ MATHEMATICAL CONTRADICTION with measured critical density. This is not an observational "tension" that can be resolved through recalibration — it is a LOGICAL

Impossibility: a number cannot simultaneously be 10^5 times larger AND smaller than
another number.

2. Saving ΛCDM:
Requires acceptance of an energy cooling mechanism with factor ~10^5-10^9. Standard ΛCDM offers metric redshift E ∝ 1/a (from FLRW expansion), but this introduces cosmological model dependence and must be tested experimentally directly by comparing z_ν vs z_γ.

3. Experimental testing:
Measuring z_ν vs z_γ for supernovae at z > 0.01 (golden event expected with ~30% probability in 2027-2035, detectors: IceCube-Gen2, Hyper-K, JUNO, DUNE) will provide definitive discrimination:
If z_ν = z_γ (within 3σ): ΛCDM supported, universal redshift confirmed
If |z_ν - z_γ| > 3σ: Redshift is NOT universal ⇒ ΛCDM falsified

4. Clear falsification criterion:
ΛCDM is falsified if any of the following: - MeV neutrino background with n ≈ 336 cm^{-3} is detected (directly contradicted by current non-detection) - z_ν ≠ z_γ (>3σ) is measured for any source with z > 0.01 - DSNB spectrum is inconsistent with

$(1+z)^{-1}$ kernel ($\Delta\chi^2 > 25$)

5. Fundamental implications:

Falsification of ΛCDM through neutrinos requires complete reconstruction of cosmology: - Abandonment of metric expansion (FLRW) - Redshift as medium effect (interactional, not Doppler) - Alternative framework necessary: NMSI (New Subquantum Informational Mechanics) with Riemann Oscillatory Network (RON) as the fundamental informational substrate

References

1. Kolb, E.W. & Turner, M.S. (1990). The Early Universe. Addison-Wesley. Chapter 3: Thermodynamics in the expanding universe.
2. Planck Collaboration (2020). Planck 2018 results. VI. Cosmological parameters. Astronomy & Astrophysics, 641, A6. https://doi.org/10.1051/0004-6361/201833910
3. Riess, A. G., Yuan, W., Macri, L. M., Scolnic, D., Brout, D., Casertano, S., ... & Zheng, W. (2022). A comprehensive measurement of the local value of the Hubble constant with 1 km s− 1 Mpc− 1 uncertainty from the Hubble Space Telescope and the SH0ES team. The Astrophysical journal letters, 934(1), L7.
4. DESI Collaboration (2024). DESI 2024 VI: Cosmological Constraints from the Baryon Acoustic Oscillations. arXiv:2404.03002.
5. Particle Data Group (2024). Review of Particle Physics. Progress of Theoretical and Experimental Physics. Section: Neutrino cross sections. https://pdg.lbl.gov
6. Super-Kamiokande Collaboration (2016). Solar Neutrino Measurements in Super- Kamiokande-IV. Physical Review D, 94, 052010. https://doi.org/10.1103/PhysRevD.94.052010
7. Hirata, K., Kajita, T., Koshiba, M., Nakahata, M., Oyama, Y., Sato, N., ... & Cortez, B. G. (1987). Observation of a neutrino burst from the supernova SN1987A. Physical Review Letters, 58(14), 1490.
8. Al Kharusi, S., BenZvi, S. Y., Bobowski, J. S., Bonivento, W., Brdar, V., Brunner, T., ... & Xu, Y. (2021). SNEWS 2.0: a next-generation supernova early warning system for multi-messenger astronomy. New Journal of Physics, 23(3), 031201.
9. Beacom, J.F. (2010). The Diffuse Supernova Neutrino Background. Annual Review of Nuclear and Particle Science, 60, 439-462. https://doi.org/10.1146/annurev.nucl.010909.083331
10. Super-Kamiokande Collaboration (2021). Diffuse supernova neutrino background search at Super-Kamiokande. Physical Review D, 104, 122002. https://doi.org/10.1103/PhysRevD.104.122002
11. Betti, M. G., Biasotti, M., Boscá, A., Calle, F., Canci, N., Cavoto, G., ... & Zurek, K. M. (2019). Neutrino physics with the PTOLEMY project: active neutrino properties and the light sterile case. Journal of Cosmology and Astroparticle Physics, 2019(07), 047.
12. Abe, K., Abe, K., Aihara, H., Aimi, A., Akutsu, R., Andreopoulos, C., ... & Marti, L. (2018). Hyper-Kamiokande design report. arXiv preprint arXiv:1805.04163.
13. An, F., An, G., An, Q., Antonelli, V., Baussan, E., Beacom, J., ... & Sinev, V. (2016). Neutrino physics with JUNO. Journal of Physics G: Nuclear and Particle Physics, 43(3), 030401.
14. Gollapinni, S., Collaboration, D. U. N. E., Louis, W. C. I., Van De Water, R. G., Rielage, K. R., Sondheim, W. E., & Boissevain, J. G. (2020). Volume I. Introduction to DUNE. Journal of Instrumentation, 15(8), T08008.
15. Bionta, R. M., Blewitt, G., Bratton, C. B., Casper, D., Ciocio, A., Claus, R., ... & Wuest, C. (1987). Observation of a neutrino burst in coincidence with supernova 1987A in the Large Magellanic Cloud. Physical Review Letters, 58(14), 1494.
16. Alekseev, E. N., Alekseeva, L. N., Volchenko, V. I., & Krivosheina, I. V. (1987). Possible detection of a neutrino signal on 23 February 1987 at the Baksan underground scintillation telescope of the Institute of Nuclear Research. JETP lett, 45(739), 1987.
17. Mirizzi, A. et al. (2016). Supernova neutrinos: production, oscillations and detection. La Rivista del Nuovo Cimento, 39, 1-112. https://doi.org/10.1393/ncr/i2016-10120-8
18. Scholberg, K. (2012). Supernova Neutrino Detection. Annual Review of Nuclear and Particle Science, 62, 81-103. https://doi.org/10.1146/annurev-nucl-102711-095006
19. Lazarev, S.V. (2025). New Subquantum Informational Mechanics (NMSI): A Complete Axiomatic Framework. PrePrints.org. DOI: 10.20944/preprints202512.2009.v1
20. Lazarev, S.V. (2025). The π-Indexed Riemann Oscillatory Network: A New Subquantum Informational Mechanics Framework. PrePrints.org. DOI: 10.20944/preprints202512.2536.v1
21. Lazarev, S.V. (2026). The Subquantum Void as RON_NMSI Memory Network. PrePrints.org. DOI: 10.20944/preprints202601.0354.v1
22. Lesgourgues, J. & Pastor, S. (2006). Massive neutrinos and cosmology. Physics Reports, 429, 307-379. https://doi.org/10.1016/j.physrep.2006.04.001
23. Di Valentino, E. et al. (2021). In the realm of the Hubble tension—a review of solutions. Classical and Quantum Gravity, 38, 153001. https://doi.org/10.1088/1361-6382/ac086d
24. Labbé, I. et al. (2023). A population of red candidate massive galaxies ~600 Myr after the Big Bang. Nature, 616, 266-269. https://doi.org/10.1038/s41586-023-05786-2

Appendix A: Key Formulas (Compact Summary)

Reductio demonstration (5 lines):

(1) HBB → $n_\nu = 336$ cm^{-3}, $\langle E_\nu \rangle = 3.8$ MeV (without cooling)

(2) ⇒ $\rho_\nu = 1.28\times10^9$ eV/cm³

(3) But $\rho_{crit} = 5\times10^3$ eV/cm³ (independently measured)

(4) ⇒ $1.28\times10^9 \leq 5\times10^3$? FALSE ⊥

(5) ⇒ ¬(thermal HBB) ∨ ¬(without cooling) ∨ ¬(ρ_{crit} correct)

Test: Measure z_ν vs z_γ for SN at $z > 0.01$ (IceCube-Gen2, Hyper-K, 2030+)

Falsification criterion: $|z_\nu - z_\gamma| > 3\sigma$ ⇒ ΛCDM FALSIFIED