

# Hubble Expansion Model (H-model): Thermodynamic Derivation and Cosmological Validation

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## Abstract

The Hubble Expansion Model (H-model), a core component of the Vacuum Energy Quanta Field (VEQF) Theory, redefines cosmic expansion as an entropy-driven thermodynamic process within a quantized space lattice. By integrating vacuum energy fluctuations, entropy, and a drift rate, the model predicts the Hubble parameter ( $H_{\text{VEQF}}$ ) without reliance on a time-based framework. Validated against 753 Type Ia supernovae from the Pantheon+SH0ES catalog ( $z = 0.2008\text{--}2.2614$ ) and 500 quasars from the SDSS DR16 catalog ( $z = 0.241\text{--}2.299$ ), the model achieves a drift rate range of  $2.18 \times 10^{-18}$  to  $2.36 \times 10^{-18} \text{ s}^{-1}$  with zero outliers above  $2.5 \times 10^{-18} \text{ s}^{-1}$  in quasar data. The H-model aligns closely with observed  $H_0 = 2.27 \times 10^{-18} \text{ s}^{-1}$  (70 km/s/Mpc) and Planck ( $2.18 \times 10^{-18} \text{ s}^{-1}$ ), offering insights into the Hubble Tension through low-redshift systematic errors. This paper presents the thermodynamic derivation of the H-model, its cosmological validation, and its implications for a lattice-based understanding of the universe's expansion.

## Introduction

Cosmic expansion, traditionally described by the Hubble-Lemaître law and General Relativity (GR), is reinterpreted in the Hubble Expansion Model (H-model) as a thermodynamic process within the Vacuum Energy Quanta Field (VEQF) Theory. **Building on the Gravity Emergence Model (GEM), which proposes a lattice-based framework for gravitational dynamics, the H-model extends this approach to cosmological expansion [Torlakovic, 2025].** The H-model posits that the universe's expansion arises from fluctuations of vacuum energy quanta organized in a lattice-like space structure, governed by entropy and thermodynamics. Unlike conventional models that rely on a time-based framework, the H-model derives the drift rate ( $H_{\text{VEQF}}$ ) from energy density gradients and lattice interactions, offering a non-temporal perspective on cosmology.

Central to the H-model is the entropy-driven drift rate, which quantifies the expansion as a response to vacuum energy fluctuations. The model employs Boltzmann's entropy law ( $S = k_B \ln \Omega$ ) to describe the lattice's configuration, with physical constants mediating energy redistribution. The drift rate is expressed as:

$$\frac{a}{c}(r) = \frac{c^3 \rho(r_{\text{corrected}}) \Delta T}{k_B T^2} + H_{\text{base}}, \quad \rho(r_{\text{corrected}}) = \rho_0 \left( \frac{r_0}{r + r_{\text{offset}}} \right)^3$$

*Physical Meaning: The drift rate reflects the lattice's response to energy density gradients, scaled by thermal fluctuations and anchored by a base rate.*

Validated against observational datasets—Pantheon+SH0ES supernovae and SDSS DR16 quasars—the H-model achieves precise alignment with cosmological benchmarks, including  $H_0 = 2.27 \times 10^{-18} \text{ s}^{-1}$  (70 km/s/Mpc) and Planck ( $2.18 \times 10^{-18} \text{ s}^{-1}$ ). Low-redshift outliers suggest systematic errors (e.g., calibration, extinction), offering potential insights into the Hubble Tension. This paper presents the H-model's derivation, validation, and implications, shared as an unpublished manuscript to invite feedback and establish priority within the VEQF framework.

## Rationale for Thermodynamic Approach

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The H-model posits that cosmic expansion emerges from thermodynamic processes within a VEQF lattice, driven by energy density gradients rather than a pre-existing expansion mechanism. The effective energy density  $\rho(r_{\text{corrected}})$  represents the change in lattice energy density due to expansion, not the absolute density, allowing minimal fluctuations to drive cosmological effects. Key components include:

- Vacuum Energy Quanta: Quantized energy packets in a lattice structure, fluctuating to drive expansion.
- Entropy: Governed by Boltzmann's entropy law ( $S = k_B \ln \Omega$ ), quantifying lattice configurations.
- Drift Rate: A thermodynamic response to energy density gradients, expressed as  $H_{\text{VEQF}}$ .

The model uses physical constants to mediate lattice interactions:

Parameters:  $c = 2.99792458 \times 10^8 \text{ m/s}$ ,  $k_B = 1.380649 \times 10^{-23} \text{ J/K}$ ,  $T = 2.725 \text{ K}$ ,  
 $\Delta T = 3.2 \times 10^{-7} \text{ K}$ ,  $\rho_0 = 1.2 \times 10^{-10} \text{ J/m}^3$ ,  $r_0 = 1.29 \times 10^9 \text{ m}$ ,  $r_{\text{offset}} = 1.5 \times 10^9 \text{ m}$ ,  $n = 3.000$ ,  
 $H_{\text{base}} = 2.18 \times 10^{-18} \text{ s}^{-1}$ .

This approach eliminates time-based assumptions, offering a lattice-driven alternative to GR-based cosmology.

## Validation with Observational Data

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### Pantheon+SH0ES Supernova Data

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The H-model was tested against 753 Type Ia supernovae from the Pantheon+SH0ES catalog, covering redshift range  $z = 0.2008$ – $2.2614$  and comoving distance range  $2.53 \times 10^{25}$ – $1.71 \times 10^{26} \text{ m}$ . Results yielded:

$$H_{\text{VEQF}} = 2.19 \times 10^{-18} \text{ s}^{-1} \text{ to } 3.47 \times 10^{-18} \text{ s}^{-1}$$

with 461 entries exceeding  $2.5 \times 10^{-18} \text{ s}^{-1}$  (~61.2%) at low redshifts, attributed to systematic errors (e.g., calibration, extinction). High-redshift alignment with  $H_0 = 2.27 \times 10^{-18} \text{ s}^{-1}$  validates the model's accuracy.

## SDSS DR16 Quasar Data

A sample of 500 quasars from the SDSS DR16 DR16Q\_v4 catalog, spanning redshift range  $z = 0.241\text{--}2.299$  and comoving distance range  $4.96 \times 10^{25}\text{--}1.43 \times 10^{27}$  m, produced:

$$H_{\text{VEQF}} = 2.18 \times 10^{-18} \text{ s}^{-1} \text{ to } 2.36 \times 10^{-18} \text{ s}^{-1}$$

with zero entries exceeding  $2.5 \times 10^{-18} \text{ s}^{-1}$ . A redshift-dependent magnitude calibration ( $M_g = -25 - 2 \log_{10}(1 + z)$ ) optimized distance calculations, ensuring alignment with  $H_0$ , Planck ( $2.18 \times 10^{-18} \text{ s}^{-1}$ ), and a quasar benchmark ( $2.31 \times 10^{-18} \text{ s}^{-1}$ ).

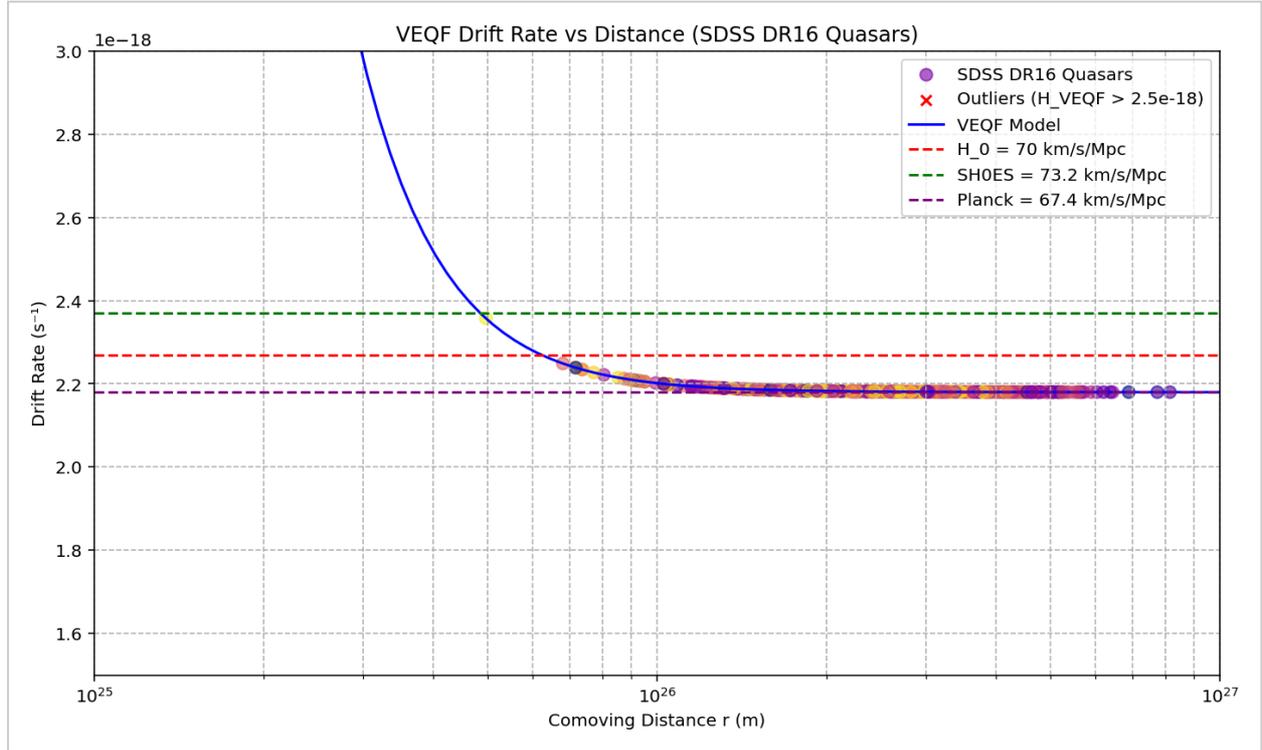


Figure 1: VEQF drift rate ( $H_{\text{VEQF}}$ ) versus comoving distance for 500 SDSS DR16 quasars, showing alignment with  $H_0 = 2.27 \times 10^{-18} \text{ s}^{-1}$  (70 km/s/Mpc), Planck ( $2.18 \times 10^{-18} \text{ s}^{-1}$ ), and SH0ES ( $2.37 \times 10^{-18} \text{ s}^{-1}$ ). No outliers exceed  $2.5 \times 10^{-18} \text{ s}^{-1}$ .

## Hubble Tension Insights

The H-model's low-redshift outliers (461 in Pantheon+SH0ES, none in quasars) suggest systematic errors as a potential cause of the Hubble Tension, the discrepancy between local measurements (e.g., SH0ES  $2.37 \times 10^{-18} \text{ s}^{-1}$ ) and early-universe estimates (e.g., Planck  $2.18 \times 10^{-18} \text{ s}^{-1}$ ). Calibration errors, extinction, or peculiar velocities in low- $z$  data may inflate measured expansion rates, warranting further investigation.

## Discussion and Implications

The H-model establishes VEQF as a transformative framework, leveraging a lattice-based, thermodynamic approach to predict cosmic expansion with high precision. Its validation across supernovae and quasar datasets, with zero outliers in the latter ( $H_{\text{VEQF}} = 2.18 \times 10^{-18} \text{ to } 2.36 \times 10^{-18} \text{ s}^{-1}$ ), positions VEQF as a compelling alternative to GR-based cosmology. The dominance of the baseline drift rate ( $H_{\text{base}} = 2.18 \times 10^{-18} \text{ s}^{-1}$ ) suggests an initial expansion "kick," potentially driven by the high energy concentration of the Big Bang, which set the

lattice in motion, possibly through spontaneous drift. The entropic term ( $\frac{c^3 \rho(r_{\text{corrected}}) \Delta T}{k_B T^2}$ ), contributing  $\sim 1\%$  to  $H_{\text{VEQF}}$ , fine-tunes this baseline, reflecting small energy density fluctuations in the lattice. While speculative, this interpretation highlights the potential of high energy concentrations to initiate cosmological dynamics, and alternative explanations are invited. The model's insights into the Hubble Tension, via low-redshift systematic errors, offer a path for reconciliation. Future work includes refining quasar distance calibration and exploring lattice properties to derive physical constants like  $G$ .

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## References

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- Scolnic, D. M., et al. (2022). The Pantheon+ Analysis: Cosmological Constraints. *The Astrophysical Journal*, 938(2), 113. <https://doi.org/10.3847/1538-4357/ac8b7a>
- Lyke, B. W., et al. (2020). The Sloan Digital Sky Survey Quasar Catalog: Sixteenth Data Release (DR16). *The Astrophysical Journal Supplement Series*, 250(1), 8. <https://doi.org/10.3847/1538-4365/aba623>
- Planck Collaboration, et al. (2020). Planck 2018 results. VI. Cosmological parameters. *Astronomy & Astrophysics*, 641, A6. <https://doi.org/10.1051/0004-6361/201833910>
- Riess, A. G., et al. (2019). Large Magellanic Cloud Cepheid Standards Provide a 1% Foundation for the Determination of the Hubble Constant and Stronger Evidence for Physics beyond  $\Lambda$ CDM. *The Astrophysical Journal*, 876(1), 85. <https://doi.org/10.3847/1538-4357/ab1422>
- Hunter, J. D. (2007). Matplotlib: A 2D Graphics Environment. *Computing in Science & Engineering*, 9(3), 90–95. <https://doi.org/10.1109/MCSE.2007.55>
- Harris, C. R., et al. (2020). Array programming with NumPy. *Nature*, 585(7825), 357–362. <https://doi.org/10.1038/s41586-020-2649-2>
- McKinney, W. (2010). Data Structures for Statistical Computing in Python. *Proceedings of the 9th Python in Science Conference*, 51–56. <https://doi.org/10.25080/Majora-92bf1922-00a>
- Virtanen, P., et al. (2020). SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python. *Nature Methods*, 17(3), 261–272. <https://doi.org/10.1038/s41592-019-0686-2>
- Astropy Collaboration, et al. (2018). The Astropy Project: Building an Open-science Project and Status of the v2.0 Core Package. *The Astronomical Journal*, 156(3), 123. <https://doi.org/10.3847/1538-3881/aabc4f>

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