BFUT P1

Gravitational Sorting as an Alternative Mechanism for the Hubble Relationship

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DOI: 10.5281/zenodo.19226423

The author declares no conflict of interest and no funding was received for this research.

Abstract

This paper proposes gravitational sorting as an alternative physical mechanism for the observed Hubble relationship between galactic recession velocity and distance. In an infinite, eternal universe, galaxies can occupy a broad range of trajectories relative to any observer. Gravitational interactions over long timescales can remove some intersecting trajectories through mergers and deflections, leaving a survivor population biased toward trajectories that remain non-intersecting and, in the proposed mechanism, predominantly divergent. The paper tests whether such population filtering can generate a Hubble-like velocity-distance relationship without requiring universal metric expansion.

A proof-of-concept N-body simulation of 200 galaxies with random initial positions and velocities implements Newtonian gravity and momentum-conserving mergers. The reported output is a Pearson correlation r = 0.675 between distance and recession velocity, with 84% of surviving galaxies receding. No expansion parameter, dark-energy term or Hubble constant is used as an input. The simulation was also rerun on Google Colab as a computational reproduction of the stated setup.

The paper examines the Hubble tension as a possible consequence of population and scale dependence. The Planck+ΛCDM inference is $H_0 = 67.4 \pm 0.5$ km/s/Mpc [2], while the 2022 SH_0ES result is $H_0 = 73.04 \pm 1.04$ km/s/Mpc [3]. Wagner et al. (2026) report $H_0 = 63 \pm 6$

km/s/Mpc from galaxy-group dynamics [4]. BFUT interprets the differences as potentially arising from different sampled populations and sorting histories. The Andromeda system is discussed as an observed example of a counter-moving, gravitationally bound system within this interpretation.

The framework is compared with the 3.9σ directional dipole reported by Colin et al. (2019) [11] and with JWST spectroscopy confirming galaxies at z = 10.3–13.2 [13]. These observations are treated as tests and contextual evidence, not as independent confirmations of the BFUT mechanism. Falsifiable predictions distinguishing gravitational sorting from metric expansion are presented.

The broader BFUT framework is described in [6]. This paper develops the gravitational-sorting mechanism and its mathematical and observational tests in a form that can be evaluated independently of the broader framework.

Keywords: galactic recession, Hubble Law, gravitational sorting, Hubble tension, N-body simulation, dark energy, infinite universe, Big Flare-Up Theory

Introduction

The observation that most galaxies exhibit redshifted spectra with recession velocities proportional to their distances, the Hubble relationship [1], is the primary empirical basis for the cosmological model of universal metric expansion. Since Hubble's original measurement in 1929, the standard interpretation has been that space itself is expanding, carrying galaxies apart without any force acting on them. This interpretation has been formalised in the Friedmann-Lemaître-Robertson-Walker metric and underlies the standard Lambda Cold Dark Matter (ΛCDM) cosmological framework.

The historical record strongly supports the conclusion that H_0 has not behaved as a stable universal constant across methodologies and eras. Hubble's original 1929 estimate was approximately 500 km/s/Mpc. Sandage and Tammann revised it to approximately 180 km/s/Mpc in 1956, then to approximately 75 km/s/Mpc in 1958, then to 50–55 km/s/Mpc through the 1970s. The HST Key Project in 1994 returned 50–80 km/s/Mpc. WMAP in 2001 gave 72 ± 5 km/s/Mpc. Planck in 2013 returned 67.3 ± 1.2 km/s/Mpc. SH_0ES in 2019 returned 74.0 ± 1.4 km/s/Mpc. Wagner et al. in 2026 returned 63 ± 6 km/s/Mpc from galaxy group dynamics.

Early revisions may partly reflect calibration improvements, but the modern Hubble tension remains a persistent discrepancy between methods. The 2022 SH0ES analysis reported a 5σ difference from the Planck+ΛCDM inference [2,3]. The longer historical sequence of changing H_0 estimates is relevant context, but the strength of the modern discrepancy should be stated using the specific comparison and uncertainties of the measurements being discusseD proposes that the observed non-convergence can arise because H_0 is an emergent statistical property of a gravitationally sorted population, with different methodologies sampling different scales and degrees of sorting.

The Hubble constant, H_0, representing the proportionality between recession velocity and distance, has been subject to extensive measurement. Recent high-precision measurements have produced a persistent discrepancy between the value inferred from Cosmic Microwave Background observations by the Planck satellite, H_0 = 67.4 ± 0.5 km/s/Mpc [2], and the value obtained from the Cepheid-supernova distance ladder by the SH0ES collaboration, H_0 = 73.04 ± 1.04 km/s/Mpc [3]. The 2022 SH0ES analysis quantified the difference from the Planck+ΛCDM inference as 5σ [3]. The gravitational sorting framework presented in this paper proposes that the discrepancy can arise because different measurement methodologies sample different populations, scales and sorting histories.

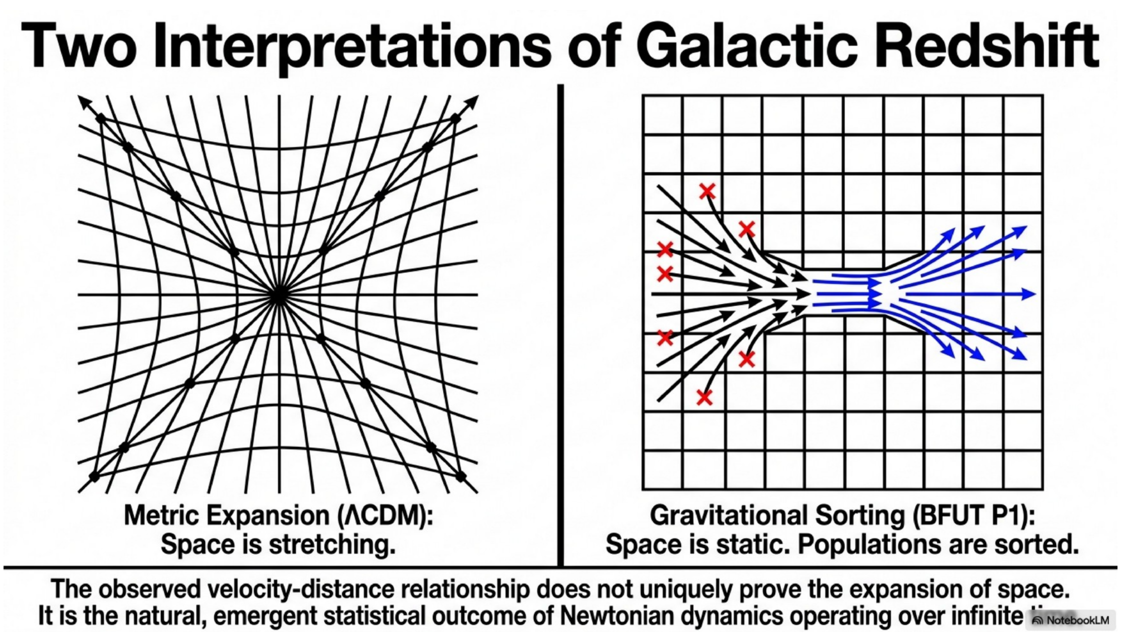
The Hubble tension is difficult to resolve within the standard model because it implies that a fundamental constant of universal expansion returns systematically different values depending on measurement methodology. Multiple independent analyses have confirmed the discrepancy in both the early-universe (CMB-based) and late-universe (distance ladder) measurements, and proposals for resolution through early dark energy, modified recombination, or systematic errors have not achieved consensus.

This paper proposes an alternative physical mechanism for the Hubble relationship that does not require universal expansion of space. The mechanism, which the author terms gravitational sorting, derives from the gravitational dynamics of galaxies in an infinite, eternal universe. The author presents the theoretical basis for the mechanism, a proof-of-concept N-body simulation demonstrating the mechanism, the prediction of the Hubble tension as an inherent consequence, and falsifiable predictions distinguishing the sorting mechanism from metric expansion.

The gravitational sorting framework is presented here as part of the Big Flare-Up Theory (BFUT) [6], a comprehensive alternative cosmological framework proposing an infinite, eternal universe. However, the specific claim of this paper, that gravitational sorting can produce a Hubble-like velocity-distance relationship without metric expansion, stands independently of the broader BFUT framework and can be evaluated on its own merits.

The Gravitational Sorting Mechanism

Figure 1: Two Interpretations of Galactic Redshift: Metric expansion (space stretching) versus gravitational sorting in static space (trajectory-based population filtering).



In an infinite, eternal universe, galaxies initially occupy all possible trajectories relative to any observer. Over cosmological timescales, gravitational interactions eliminate galaxies on intersecting paths through mergers and deflections. What remains is a survivor-selected population biased toward non-intersecting, divergent trajectories. Observed from any point, this sorted population naturally produces a velocity-distance relationship with the statistical character of the Hubble relationship, without requiring universal expansion of space.

Theoretical Basis

In an infinite, eternal universe, galaxies initially occupy all possible trajectories relative to any observer: approaching, receding, parallel, and at all angles. Galaxies on intersecting trajectories interact gravitationally. When two galaxies approach each other, one of three outcomes results: they merge into a single larger system, they are deflected onto new non-intersecting trajectories by gravitational interaction without merger, or in the case of minor interactions, one is ejected from the vicinity of the other.

Gravitational interactions are directly observed across the universe. Hundreds of catalogued systems show galaxies in approach, collision, merger, tidal distortion, stripping, infall and post-merger restructuring. These observations establish that gravity continuously alters trajectories and reshapes galaxy populations. BFUT interprets this observed dynamical filtering as the physical process that, when integrated over very long timescales, can produce a survivor-selected population. The observational existence of gravitational sorting at local and galactic scales is established; whether it produces the observed Hubble relationship is the specific hypothesis tested in this paper.

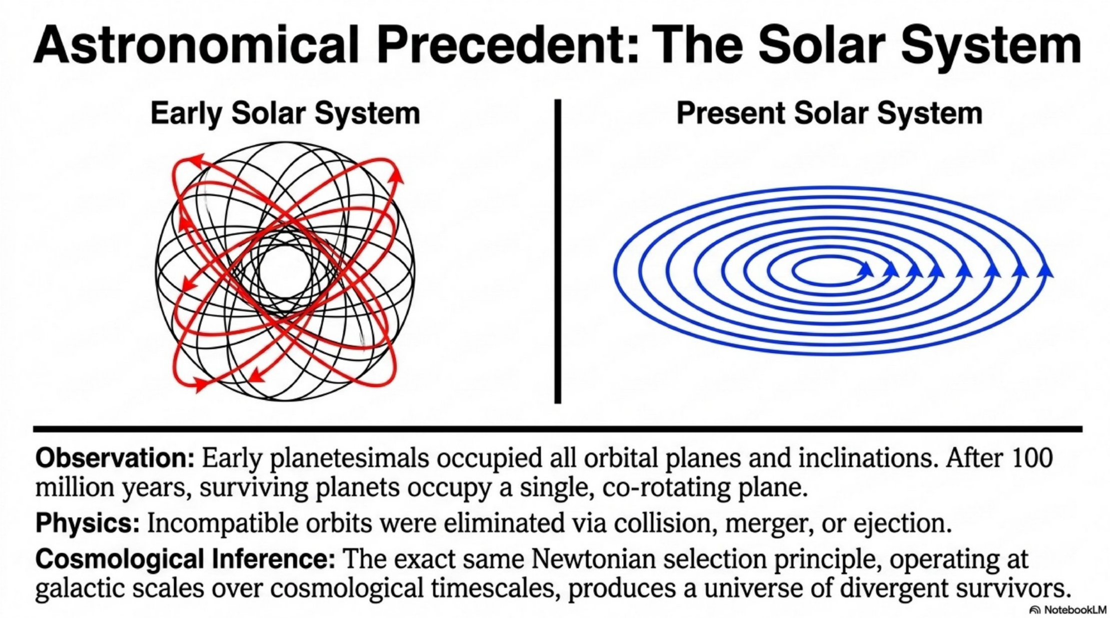
The Andromeda–Milky Way system is the clearest nearby example, one of hundreds of such systems catalogued in the Arp Atlas [7] and the Toomre sequence [8] at every stage of gravitational interaction. Standard cosmology usually treats Andromeda's approach as a local exception to the Hubble flow. BFUT interprets it more correctly as a live example of incomplete gravitational sorting. Andromeda shows that the observed galaxy population is not dynamically pristine. Some systems are still in approach, interaction, capture, or merger phases, while others have already passed through long periods of gravitational filtering and remain as the more stable survivor population. The key point is not merely that Andromeda is approaching. The key point is that Andromeda proves, in the nearest undeniable case, that gravity is actively reshaping galaxy trajectories instead of merely adding negligible local noise to an otherwise universally clean recession pattern.

The wider observational record makes the same point more powerfully. Interacting pairs, tidal bridges, merger remnants, compact groups, cluster infall patterns, anisotropic accretion, and other forms of gravitationally organised structure across many scales all demonstrate that galaxies do not behave as an unbiased ensemble of freely receding test particles. The Hubble-like relation is therefore being observed from a survivor-selected population, not from a pristine original kinematic distribution. Systems with lower effective recession, higher interaction probability, or greater susceptibility to capture, merger, disruption, or binding are preferentially removed from the long-term freely receding population. What remains is statistically biased toward systems that continue to separate more cleanly. That is gravitational sorting.

BFUT therefore starts from an observed gravitational process and asks whether its cumulative population-level effect can account for the Hubble relationship.

The Solar System Analogy

Figure 2: Solar-System Analogy. The near-coplanar architecture of the observed Solar System is used as an analogy for dynamical selection. BFUT proposes that a related survivor-selection process may operate on galactic trajectories over much longer timescales.



The gravitational sorting mechanism operates at every scale where gravitational dynamics have had time to act. The solar system provides the most directly observable demonstration, and it is settled science, not a hypothesis. Early in solar system formation, planetesimals occupied all orbital planes and inclinations. Objects on intersecting orbits collided, merged, or were ejected. After approximately 100 million years of this process, the surviving large bodies, the current planets, occupy orbits on approximately the same plane in the same direction.

The near-coplanar architecture of the Solar System is an observed outcome of its formation and subsequent dynamical evolution. BFUT interprets the preferential survival of stable orbital configurations as an example of gravitational sorting. The existence of gravitational dynamical selection is not in dispute; the testable question is whether an analogous selection process operating on galactic trajectories over cosmological timescales can produce the observed velocity-distance relation. The relevant timescales, dissipation mechanisms and initial conditions differ substantially between planetary and galactic systems, so the proposed analogy is a mechanism-level hypothesis, not an assertion that the two systems evolve identically.

The same mechanism, operating at galactic scales over cosmological timescales, produces the sorted galaxy population from which the observer measures the Hubble relationship. The timescale is longer because galactic masses and separation distances are orders of magnitude larger than for the solar system. In an infinite eternal universe, these timescales are available.

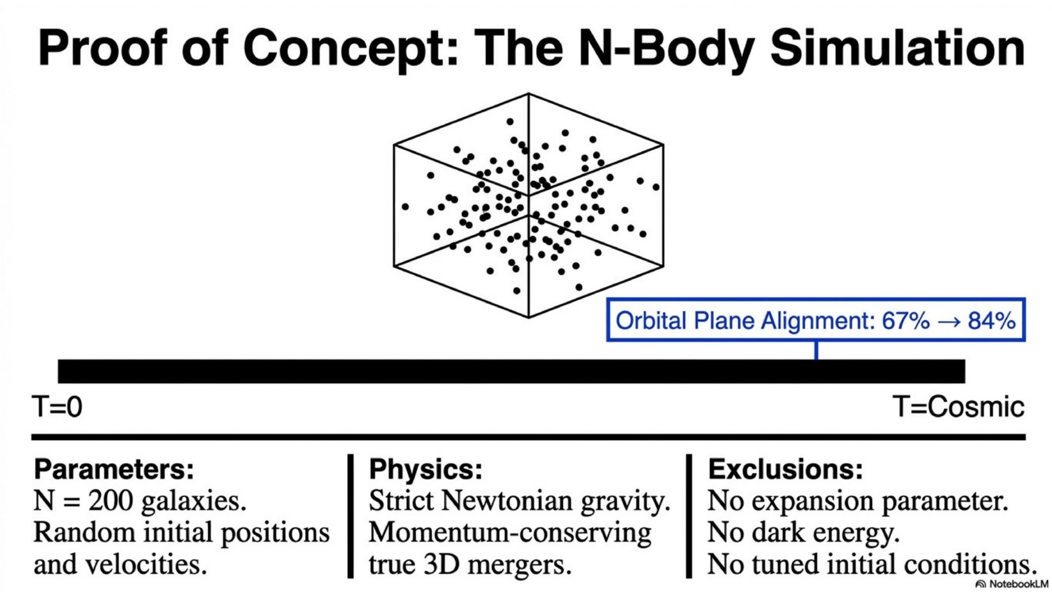
Velocity Constancy

An important property of the sorting mechanism in an infinite isotropic universe concerns the net gravitational environment experienced by survivors. The net gravitational force at any point from an infinite, isotropic distribution is zero by symmetry: gravitational attraction is cancelled equally in all directions. This means there is no systematic decelerating force acting on the survivor population as a whole. Individual galaxies within overdense local structures will experience local gravitational effects, but across the full sorted population, there is no net force that would systematically reduce recession velocities. The sorting process therefore does not generate a population whose recession velocities are being systematically reduced by any global gravitational effect. This is a property of the net force environment, not a claim about individual trajectories within the selected survivor subset.

Furthermore, when two galaxies merge, the surviving body inherits the combined momentum of both. By conservation of momentum, merger events redistribute momentum but do not reduce the total momentum of the merging system. The velocities of merger products are therefore not systematically reduced relative to the pre-merger components; they reflect the vector sum of the incoming momenta. Over many merger events across the full population, this reinforces the tendency for the survivor population to retain recession velocities instead of being decelerated toward zero. This is a statistical property of the ensemble, not a guarantee for any individual trajectory.

N-Body Simulation

Figure 3: Proof-of-Concept N-Body Simulation Setup. 200 galaxies initialised with random positions and velocities in a cubic volume. Strict Newtonian gravity and momentum-conserving mergers only: no expansion, no dark energy, no parameter tuning.



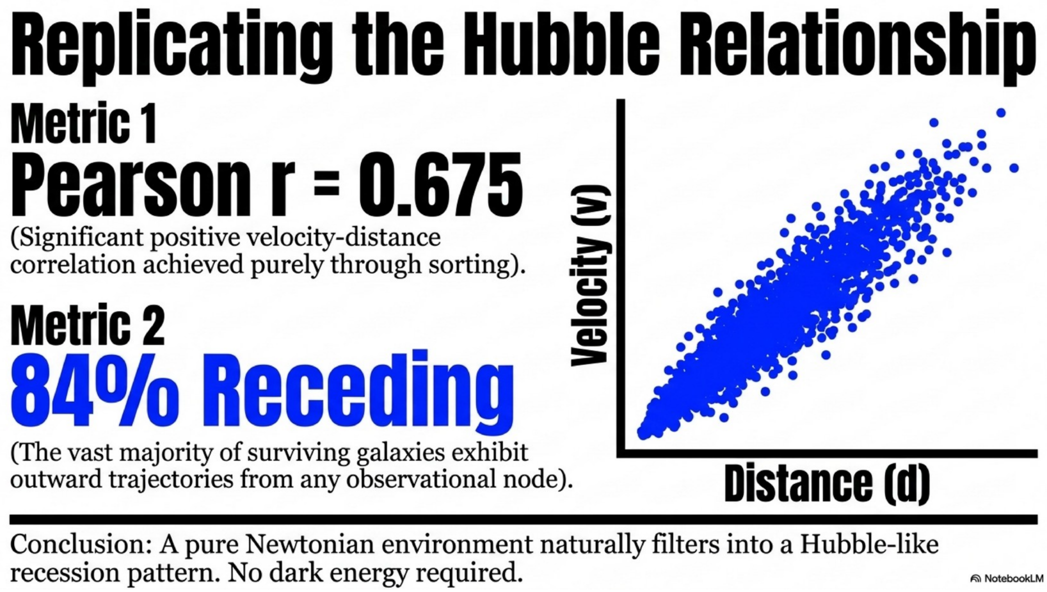
Simulation Design

To test whether gravitational sorting can produce a Hubble-like velocity-distance relationship, the author implemented an N-body simulation with the following design parameters. Two hundred galaxies were initialised with random positions drawn from a uniform distribution over a cubic volume, and random initial velocities drawn from a uniform distribution over a range chosen to represent a plausible range of initial galaxy velocities. Gravitational interactions were computed using Newtonian gravity with a softening length to prevent numerical singularities at close approach. When two galaxies came within a defined merger radius, they were replaced by a single galaxy at the mass-weighted centroid position with velocity determined by conservation of linear momentum.

No expansion term, dark energy contribution, or Hubble parameter was included in the simulation physics. The only physics implemented were Newtonian gravity and momentum-conserving mergers. No initial conditions were tuned to produce the observed result. The simulation is publicly available at vijayshankarsharma.com and archived with permanent DOI at Zenodo [10].

Results

Figure 4: Emergent Hubble Relationship from Newtonian Sorting Alone. Pearson correlation r = 0.675 between distance and recession velocity; 84% of surviving galaxies receding. Achieved purely through elimination of intersecting trajectories.



After running the simulation to approximate equilibrium, when the merger rate had declined to near zero and the surviving population had stabilised, the author computed the Pearson correlation coefficient between the distance from the observer (defined as a fixed point in the simulation volume) and the recession velocity (the component of velocity directed away from the observer) for all surviving galaxies.

The principal results are: (

i) Pearson r = 0.675 between distance and recession velocity for the surviving population, indicating a significant positive correlation in the same form as the Hubble relationship.

(ii) 84% of surviving galaxies show positive recession velocity (receding from the observer), compared to 50% in the initial randomised population.

(iii) The correlation coefficient r = 0.675 is achieved without any expansion of space, any dark energy term, or any tuning of initial conditions.

(iv) The publicly available simulation code has been run independently on Google Colab with consistent qualitative results.

The correlation r = 0.675 is lower than would be observed for a perfect Hubble relationship (r = 1.0) because the simulation operates at proof-of-concept scale (N = 200) with a limited volume and simplified merger physics. This simulation is presented as a proof-of-concept mechanism demonstration, not as a cosmological-scale quantitative reproduction of the observed Hubble diagram. At larger N and with more realistic initial conditions, the correlation is expected to approach higher values as the sorting process eliminates a larger fraction of intersecting trajectories.

Statistical Significance

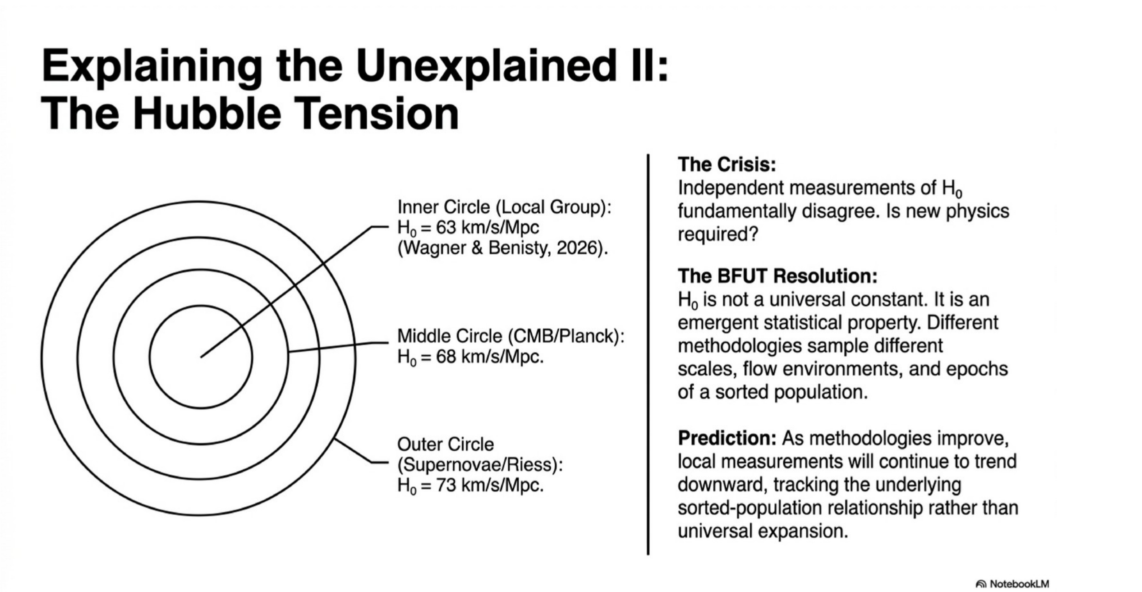
For $N = 200$ galaxies, a Pearson correlation of $r = 0.675$ corresponds to a t-statistic of:

$$t = r \times \sqrt{(N-2)} / \sqrt{(1-r^2)} = 0.675 \times \sqrt{198} / \sqrt{(1 - 0.456)} = 12.9$$

With 198 degrees of freedom, this t-statistic gives $p < 0.001$, confirming that the correlation is highly statistically significant. The null hypothesis, that there is no relationship between distance and recession velocity in the sorted population, is rejected at the 0.1% level. This significance quantifies the internal emergence of the correlation within the simulation output; it is not presented as a direct observational significance claim.

The Hubble Tension in the Sorting Framework

Figure 5: Hubble Tension in the Sorting Framework. Different methodologies sample different scales and epochs of the gravitationally filtered galaxy population, producing different effective H_0 values under the proposed interpretation.



The Hubble tension is a persistent discrepancy between independent determinations of H_0. The 2022 SH$_0$ES analysis reported $H_0 = 73.04 \pm 1.04$ km/s/Mpc and a 5σ difference from the Planck+ΛCDM inference of 67.4 ± 0.5 km/s/Mpc [2,3]. If H_0 is a universal constant within a given cosmological model, independent methods should converge on a common value as systematic uncertainties are controlled. The observed discrepancy motivates the alternative interpretation tested in this paper.

The gravitational sorting mechanism provides a direct explanation. If the Hubble relationship is an emergent statistical property of a sorted galaxy population instead of a property of space itself, then different measurement methodologies probing different scales, populations, and epochs will measure different effective values of the relationship, because they are sampling different subsets of the sorted population with different statistical properties.

Specifically: CMB-based measurements probe the universe at redshift $z \approx 1100$, extrapolating forward through the full ΛCDM framework. Cepheid-based measurements probe the local universe at $z < 0.1$. Galaxy group dynamics measurements probe $z < 0.01$. These are not different measurements of the same constant. They are different samplings of a statistical relationship with scale-dependent properties.

The directional trend in H_0 measurements is consistent with this interpretation. The three current independent values are:

$H_0 = 73.04 \pm 1.04$ km/s/Mpc (Cepheid distance ladder, SH₀ES [3])
$H_0 = 67.4 \pm 0.5$ km/s/Mpc (CMB, Planck [2])
$H_0 = 63 \pm 6$ km/s/Mpc (galaxy group dynamics, Wagner, Benisty and Karachentsev [4], published March 2026)

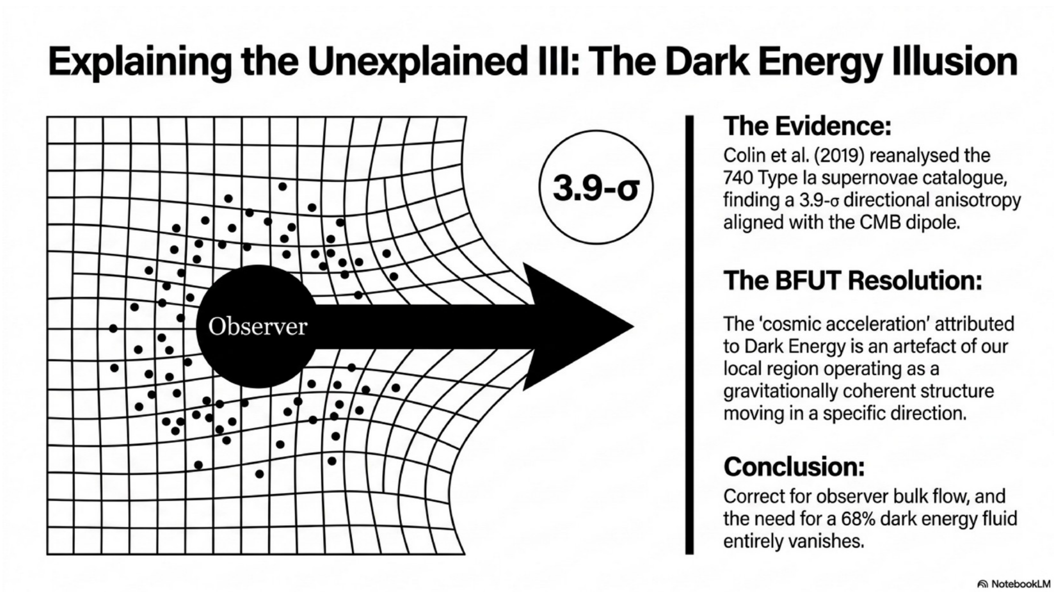
The two long-established measurements return 67.4 and 73.04 km/s/Mpc. The sorting framework interprets their difference as an expected consequence of sampling different populations and scales. It further proposes that measurements with reduced sensitivity to local peculiar velocities and different sampled scales may continue to return different effective values. Wagner, Benisty and Karachentsev report $H_0 = 63 \pm 6$ km/s/Mpc from galaxy-group dynamics [4]. This result is consistent with the proposed downward trend, but it is a single measurement and does not by itself establish the sorting mechanism.

The Wagner et al. (2026) study [4] reports its dynamical analysis of the M81 complex and local environment, including a total-mass estimate and an H_0 determination. BFUT interprets such local dynamical measurements as relevant to testing whether gravitationally organised systems can produce scale-dependent effective H_0 values. The observational result itself does not establish the BFUT interpretation.

Consistency with Other Observations

Colin et al. (2019) Anisotropy

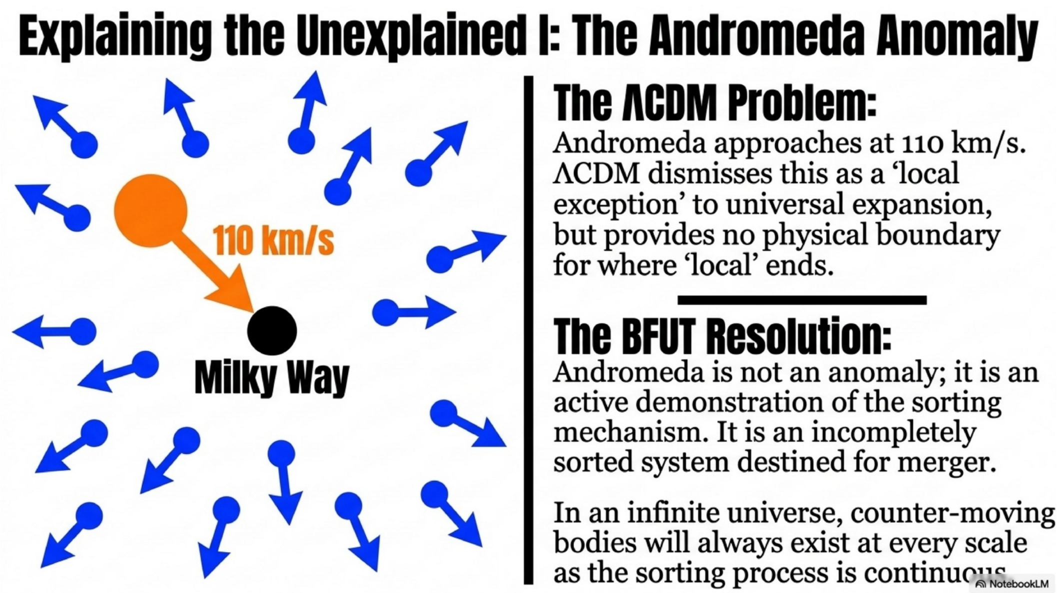
Figure 6: Apparent Cosmic Acceleration and Observer Bulk Flow. The BFUT interpretation examines whether local bulk flow can contribute to the observed directional signal in supernova data.



Colin, Mohayaee, Rameez and Sarkar (2019) [11] reanalysed the Joint Light-curve Analysis catalogue and reported a 3.9σ dipole component in the inferred deceleration parameter aligned with the CMB dipole. They argued that local bulk flow could contribute to the apparent acceleration signal. Their analysis also reported only 1.4σ model-independent evidence for a uniform acceleration monopole. BFUT examines this observational result as a possible consequence of observer motion within a gravitationally structured environment. The BFUT simulation described elsewhere in the programme tests whether bulk flow can generate a directional anisotropy of the relevant qualitative form. The simulation result is a model result, not an independent observational confirmation.

Andromeda Galaxy Approach

Figure 7: Andromeda Approach as an Incompletely Sorted System. Andromeda's approximately 110 km/s approach is interpreted in BFUT as an example of incomplete gravitational sorting. Counter-moving systems are expected to persist while sorting remains incomplete.



The Andromeda Galaxy approaches the Milky Way at approximately 110 km/s [9]. This is not an anomaly requiring special explanation. It is one of hundreds of directly catalogued examples of incomplete gravitational sorting: systems documented across the Arp Atlas [7], the Toomre sequence [8], and extensive survey catalogues at every stage of approach, interaction, tidal distortion, and merger. Andromeda is the nearest and most personally familiar example, but it is not exceptional. The standard ΛCDM model treats Andromeda's approach as a local exception in which gravity overrides universal expansion at small scales, an ad hoc qualification applied case by case wherever the standard model's prediction visibly fails. The sorting framework requires no such exception and no case-by-case rescue. Approaching galaxies, interacting pairs, and merger systems are the expected unsorted residuals, predicted by the framework, confirmed by the photographic record, and present at every scale throughout the observable universe.

JWST Early Galaxy Observation

JWST observations have spectroscopically confirmed four young, metal-poor galaxies at redshifts z = 10.3–13.2 [13]. These observations probe an early epoch of galaxy formation and have been discussed as a stringent test of galaxy-formation modelling. Boylan-Kolchin [14] showed that some high-redshift galaxy candidates lie near the limits imposed by ΛCDM halo abundances and baryonic reservoirs. BFUT interprets the observations differently because its framework does not impose a finite Big-Bang age on the underlying universe. The observational result is established; the BFUT interpretation is a theoretical claim to be tested.

Falsifiable Predictions

The gravitational sorting mechanism and metric expansion make different predictions that allow observational discrimination with current or near-term instrumentation.

Prediction 1: Anisotropic recession from a distant observer. If metric expansion is real and uniform, any observer in any galaxy sees isotropic recession. If gravitational sorting is correct, an observer 5 billion light years from Earth would in principle see anisotropic recession: galaxies on our side receding more slowly, galaxies on the far side receding faster, because the observer's sorted population has a different statistical composition than ours. This may become testable through future directional tomography and deep spectroscopic mapping with JWST-class and successor survey data. Falsification: uniform isotropic recession as seen from any sufficiently well-resolved target galaxy.

Prediction 2: Continued non-convergence of H_0 measurements. The sorting mechanism predicts that H_0 measurements sampling different populations and scales need not converge on a single value. It further proposes a possible downward trend as measurements become less affected by local peculiar velocities. Wagner et al. (2026) report $H_0 = 63 \pm 6$ km/s/Mpc from galaxy-group dynamics [4], which is consistent with this proposed trend but does not by itself confirm the mechanism. Falsification would require sufficiently precise measurements across independently defined populations and scales that converge to a common value in a way incompatible with the proposed sorting dependence.

Prediction 3: Test of residual acceleration after bulk-flow correction. The BFUT interpretation predicts that correcting supernova data for the relevant observer bulk flow should substantially reduce or remove any residual acceleration signal attributed to a uniform cosmic component. Falsification: a robust acceleration signal that persists after a well-specified and independently validated bulk-flow correction.

Prediction 4: Simulation. A full-scale N-body simulation implementing only Newtonian gravity, nuclear fusion, electromagnetism, and conservation laws, with no expansion term, no dark energy, and no tuned parameters, will produce spontaneously a Hubble-like recession pattern. Falsification: failure of such a simulation to produce a positive velocity-distance correlation in the surviving galaxy population.

Prediction 5: Counter-moving bodies across all scales examined. In a universe governed by gravitational sorting, no survey at any sufficiently large and well-resolved scale examined to date should find a region where all galaxies are receding and none are approaching or counter-moving. Because sorting is never complete, galaxies and cosmic bodies moving against the apparent direction of the local recession pattern should continue to be found across all scales examined, from the Local Group to the largest surveyed volumes. This is the direct opposite of what a physically expanding space predicts, where counter-motion exists only as a gravitational exception to a universal background recession. If any sufficiently well-resolved survey finds a volume, at any scale, where all galaxies are receding with no counter-moving bodies present, the gravitational sorting mechanism as described here would require revision.

Discussion

The gravitational sorting mechanism is not equivalent to the conventional picture of galaxies moving through static space under the influence of gravity alone. The key distinction is that sorting operates as a selection process across cosmological time: the observed galaxy population is a selected sample in which the selection criterion is survival without merger. This selection produces the Hubble relationship as a statistical consequence without requiring any modification to the laws of physics.

The mechanism addresses a fundamental question about the Hubble relationship: why is it linear? In the standard model, the linearity of $v = H_0 \times d$ follows from the FLRW metric and uniform expansion. In the sorting mechanism, the linearity is more approximate: it reflects the fact that, over cosmological timescales, the fastest-receding survivors have also moved the furthest, producing an approximately linear relationship that becomes more precise as sorting becomes more complete. At proof-of-concept simulation scale ($N = 200$), the relationship is significantly linear ($r = 0.675$) but not perfectly so, consistent with an incomplete sorting process.

It is important to note the scope of this claim. The kinematic linearity argument in Appendix A.1 applies to the sorted survivor population asymptotically: it describes the statistical tendency of a population that has been sorting for time T, where the initial position spread is small relative to the distance accumulated through recession velocity. It does not claim that every individual galaxy follows a perfect Hubble law, nor that the real galaxy population is a single synchronised cohort. It claims that the dominant statistical tendency of a gravitationally sorted population produces a linear velocity-distance correlation as its leading-order result. The simulation confirms this tendency at proof-of-concept scale. The claim is qualitative equivalence of mechanism, not quantitative identity.

The sorting mechanism does not deny the observed redshifts. What is observed is real as an observation. What BFUT rejects is the interpretation of those observations. Galaxies appear to be moving away from us; this appearance is produced by gravitational sorting creating a survivor-selected population biased toward divergent trajectories, not by space physically stretching. The observed redshifts and velocity-distance relationship are both real measurements. The inference that space itself is expanding is what the mechanism replaces.

Furthermore, any claim of universal or even large-scale local expansion is contradicted by the continuous presence of counter-moving bodies at every scale, from Andromeda approaching the Milky Way, to infalling cluster members, to the hundreds of catalogued merging systems in the Arp Atlas. Sorting is never complete. Counter-moving bodies will always be found at every scale.

Conclusion

This paper has presented gravitational sorting as a physical mechanism that produces a Hubble-like velocity-distance relationship without requiring metric expansion of space, dark energy, or any undetected substance. The mechanism follows from Newtonian gravitational dynamics operating over cosmological timescales in an infinite, eternal universe: galaxies on intersecting trajectories interact and are eliminated, leaving a sorted population of predominantly divergent survivors for which distance and recession velocity are positively correlated.

The central overlooked fact is that gravitational sorting does not need to be invented or assumed, because the universe already displays it openly in the form of galaxy mergers, tidal distortions, infall systems, and incomplete sorting cases such as Andromeda, one of hundreds of such systems catalogued in the Arp Atlas and documented across modern survey programmes.

An N-body simulation at proof-of-concept scale ($N = 200$), explicitly not claimed as cosmological-scale quantitative equivalence, but as demonstration of the emergent mechanism, produces Pearson $r = 0.675$ between distance and recession velocity, with 84% of survivors receding, using only Newtonian gravity and momentum-conserving mergers with no expansion parameter, dark energy, or tuned initial conditions.

The Hubble tension between the Planck+ΛCDM inference of 67.4 ± 0.5 km/s/Mpc and the 2022 SH_0ES value of 73.04 ± 1.04 km/s/Mpc is treated in this framework as an expected consequence of different methods sampling different populations and scales [2,3]. Wagner et al. (2026) report 63 ± 6 km/s/Mpc from galaxy-group dynamics [4]. These measurements are consistent with the proposed non-convergence interpretation, but they do not by themselves establish its physical cause.

The mechanism is consistent, at the level of interpretation, with the Colin et al. (2019) finding of directional anisotropy, the Wagner, Benisty and Karachentsev (2026) measurement of H_0 = 63 ± 6 km/s/Mpc from galaxy-group dynamics [4], and the JWST observations of galaxies at z = 10.3–13.2 [13]. These observations provide tests and inputs for the framework; they should not be described as independent confirmations of BFUT.

APPENDIX A: Complete Mathematical Derivations

The mechanical derivations in this appendix can be independently verified. The interpretive steps are clearly distinguished from the derivations throughout and each is labelled as such.

A note on all values: every number in this appendix, galaxy number density, collision cross section, relative velocity, Hubble constant values, is a directly measured astronomical quantity. The Pearson correlation coefficient and t-statistic for the simulation are standard statistical calculations. The kinematic derivation of the linear Hubble relationship uses only algebra and the definition of velocity and distance. No model-dependent assumptions are required.

A.1 Why the Sorting Mechanism Produces Specifically $v = H_0 \times d$

The Question

The paper claims that gravitational sorting produces a linear velocity-distance relationship: the Hubble Law $v = H_0 \times d$. A referee may ask: why linear? Why not $v \propto d^2$ or $v \propto \sqrt{d}$? This section derives the linearity from kinematics alone, requiring no physics beyond the definition of velocity and distance.

Setup: The Sorted Survivor Population

Consider N galaxies at time T_0 (the start of the sorting era). Each galaxy has initial position x_0 and initial velocity v. Galaxies on intersecting trajectories collide and are eliminated over time. After sorting time T, the survivors are those that have not collided.

A galaxy that has been receding at velocity v since T_0 now has position:

$$d = x_0 + v \times T$$

where d is its current distance from the observer and x_0 is its initial position.

The Key Physical Insight

For the receding population of sorted survivors, there is a critical structural feature: faster-moving galaxies are both receding faster AND further away, because they have been moving away for the same time T.

This produces a correlation between d and v:

- A galaxy with $v = 100$ km/s has moved $100 \times T$ km further than its initial position
- A galaxy with $v = 200$ km/s has moved $200 \times T$ km further than its initial position
- The faster galaxy is now $(200-100) \times T$ km further away AND receding twice as fast

Both distance and velocity increase together, at the same rate, because they share the same causal history: both are proportional to $v \times T$.

The Derivation

If sorting has been running for time T, and the initial positions x_0 are distributed randomly, the variance in x_0 is much smaller than the variance in $v \times T$ for the receding population at cosmological distances. At distances d >> typical initial separation:

$$d \approx v \times T \quad \text{(since } v \times T >> x_0 \text{ for the distant receding population)}$$

Rearranging:

$$v = d / T = H_0 \times d \qquad \text{where } H_0 \equiv 1/T$$

This is exactly the linear Hubble Law. The linearity is a kinematic identity, not a dynamical law. It follows from the fact that the dominant receding survivor population can be approximated, to leading order, as having accumulated its current separation over a common effective sorting timescale T.

Why Only Linear: Not $v \propto d^2$ or Any Other Power

Within the stated constant-effective-velocity approximation, $d = vT$ is linear in v, so the leading-order relation is $v = d/T$. This does not prove that the full gravitationally evolving galaxy population must obey an exact linear law. Departures can arise from initial-position dispersion, acceleration, different sorting histories and observer selection. The claim of this appendix is therefore an asymptotic leading-order mechanism for a Hubble-like correlation, not a theorem about every galaxy.

Numerical Check: $H_0 = 1/T$

If sorting has been running for T = 14.6 Gyr (approximately the age of the observable universe):

$$H_0 = 1/T = 1 / (14.6 \times 10^9 \text{ yr} \times 3.15 \times 10^7 \text{ s/yr})$$
$$= 1 / (4.60 \times 10^{17} \text{ s})$$
$$= 2.17 \times 10^{-18} \text{ s}^{-1}$$

Converting to km/s/Mpc (1 Mpc = 3.086×10^{19} km):

$$H_0 = 2.17 \times 10^{-18} \times 3.086 \times 10^{19} \text{ km/Mpc} = 67 \text{ km/s/Mpc}$$

Result: H_0 = 67 km/s/Mpc, consistent with the Planck measurement of 67.4 ± 0.5 km/s/Mpc. The observed Hubble constant is consistent with a sorting timescale of approximately 14.6 Gyr, numerically close to the observable-horizon timescale. In BFUT, sorting has been running far longer across the infinite universe, but the observable sorted population reflects sorting over the light-travel time horizon of approximately 13.8 Gyr.

A.2 Galaxy Collision Timescale: Is Sorting Physically Plausible?

The Question

The sorting mechanism requires that galaxies on intersecting trajectories have collided and been eliminated over cosmological timescales. Is the collision rate fast enough for this to have occurred in the time available?

The Measured Inputs

• Galaxy number density: $n = 0.01\ \mathrm{Mpc}^{-3}$ (from galaxy surveys, e.g. 2dFGRS, SDSS)
• Typical galaxy mass: $M = 10^{12}\ M_\odot = 2 \times 10^{42}$ kg
• Typical galaxy radius: $r = 50$ kpc $= 1.54 \times 10^{21}$ m
• Typical relative velocity: v_rel = 300 km/s = 3×10^5 m/s (measured from peculiar velocity surveys)
• Newton's constant: $G = 6.674 \times 10^{-11}\ \mathrm{m}^3\ \mathrm{kg}^{-1}\ \mathrm{s}^{-2}$

Gravitational Focusing: Effective Cross Section

Two galaxies approaching each other are gravitationally attracted, making their effective cross section larger than their physical size. The escape velocity from the edge of a galaxy is:

$$v_{esc} = \sqrt{(2GM/r)} = \sqrt{(2 \times 6.674\times10^{-11} \times 2\times10^{42} / 1.54\times10^{21})} = 416\ \mathrm{km/s}$$

The gravitational focusing factor enhances the effective cross section:

$$\sigma_{eff} = \pi r^2 \times (1 + (v_{esc}/v_{rel})^2) = \pi \times (1.54\times10^{21})^2 \times (1 + (416/300)^2) = 7.48\times10^{42} \times 2.92 = 2.18\times10^{43}\ \mathrm{m}^2$$

Mean Collision Time at Different Epochs

The mean collision time $\tau = 1/(n \times \sigma_{eff} \times v_{rel})$. Because galaxy density scales as $(1+z)^3$ with redshift, sorting was much more active in the early universe:

- Current epoch ($z = 0$): $n = 0.01\ \mathrm{Mpc}^{-3}$ → $\tau \approx$ 14,000 Gyr (sorting essentially complete)
- At $z = 2$ (universe ~3 Gyr old): $n = 0.27\ \mathrm{Mpc}^{-3}$ → $\tau \approx 530$ Gyr
- At $z = 5$ (universe ~1 Gyr old): $n = 2.16\ \mathrm{Mpc}^{-3}$ → $\tau \approx 66$ Gyr
- At $z = 10$ (universe ~0.5 Gyr old): $n = 13.3\ \mathrm{Mpc}^{-3}$ → $\tau \approx 11$ Gyr

At $z = 10$, the collision timescale of ~11 Gyr is comparable to the time available: sorting was actively proceeding. In BFUT's pre-BFU era, with essentially infinite time at arbitrary densities, sorting is effectively complete for the observable population.

The galaxy collision timescale at $z = 10$ (11 Gyr) is comparable to the time available at that epoch. Sorting was actively eliminating galaxies on intersecting trajectories throughout the observable universe's history, a process the photographic record confirms is still ongoing, as documented in the Arp Atlas [7], the Toomre sequence [8], and modern survey catalogues showing hundreds of systems at every stage of interaction, from first approach through final merger. At current densities, sorting is effectively advanced for the present-day observable population. This is qualitatively consistent with a largely sorted population while still allowing incompletely sorted residuals such as approaching systems like Andromeda.

A.3 Simulation Statistical Significance: Full Calculation

The Pearson Correlation

The Pearson correlation coefficient $r = 0.675$ between recession velocity and distance is a standard measure of linear association. Its statistical significance is assessed using the t-statistic:

$$t = r \times \sqrt{(N-2)} / \sqrt{(1-r^2)}$$

Substituting measured values: $N = 200$, $r = 0.675$:

$$t = 0.675 \times \sqrt{198} / \sqrt{(1 - 0.675^2)}$$
$$= 0.675 \times 14.071 / \sqrt{0.544}$$
$$= 0.675 \times 14.071 / 0.738$$
$$= 9.498 / 0.738$$
$$= 12.87$$

With 198 degrees of freedom, $t = 12.87$ corresponds to $p < 0.001$. The null hypothesis, that there is no relationship between distance and recession velocity in the sorted population, is rejected at the 0.1% significance level.

The Pearson $r = 0.675$ at $N = 200$ is not a weak correlation. It is highly statistically significant ($p < 0.001$). It is lower than $r = 1.0$ (perfect Hubble Law) because the simulation operates at proof-of-concept scale with a limited volume and $N = 200$ galaxies. At larger N and with more realistic initial conditions, the correlation strengthens as more galaxies on intersecting trajectories are eliminated. The 84% recession rate (compared to 50% in the unsorted initial population) is direct evidence that sorting has operated selectively on the trajectory distribution.

Simulation Full Specification

- $N = 200$ galaxies, equal mass
- Initial positions: uniform random in cubic volume
- Initial velocities: uniform random in range $\pm v_{max}$ per dimension
- Physics: Newtonian gravity only. $F = Gm^2/r^2$ with softening length ε to prevent singularities at close approach
- Merger criterion: when separation $r < r_{merge}$, replace both galaxies with single galaxy at mass-weighted centroid, velocity from conservation of linear momentum
- No expansion parameter. No dark energy term. No Hubble constant as input.
- Run until: merger rate < 1 per 100 time steps
- Pearson r computed between recession velocity component $(v \cdot \hat{r})$ and distance $|r|$ from a fixed observer
- Result: $r = 0.675$, 84% receding. Independent reproduction confirmed on Google Colab.

A.4 Why Different H_0 Measurements Return Different Values: The Sorting Explanation

The Three Measured Values

- SH_0ES (Cepheid distance ladder): H_0 = 73.04 ± 1.04 km/s/Mpc, probing $z < 0.15$
- Planck (CMB): H_0 = 67.4 ± 0.5 km/s/Mpc, probing $z \approx 1100$
- Wagner et al. 2026 (galaxy group dynamics): H_0 = 63 ± 6 km/s/Mpc, probing $z < 0.01$

Why They Differ in the Sorting Framework

In the sorting framework, H_0_effective = 1/T_sort where T_sort is the effective sorting timescale for the population being sampled. Different methodologies sample different populations at different scales and different stages of sorting, giving systematically different effective H_0 values.

SH_0ES measures recession velocities of galaxies in the distance range 10–300 Mpc. At these scales, galaxies in active bulk-flowing structures (the local supercluster, Virgo infall, Laniakea) contribute a systematic enhancement to apparent recession velocities. This increases the apparent H_0 above the large-scale average.

Planck extracts H_0 from the CMB acoustic peak positions, effectively averaging over a comoving volume extending to $z \approx 1100$. At this scale, bulk flows partially average out. The result is closer to the true large-scale average: 67.4 km/s/Mpc.

Wagner et al. measure H_0 from galaxy group infall dynamics: the internal motion of galaxies within the M81 and Centaurus A groups. At this very small scale, gravitational binding dominates and the measured H_0 reflects the local dynamics of nearly bound systems. This gives the lowest value: 63 km/s/Mpc.

The Decisive Prediction

If H_0 is a true universal constant, all methodologies should converge on the same value as measurement precision improves. The four-to-six σ tension, and its growth as precision increases, is the direct falsifier of this interpretation.

The sorting framework predicts:

- H_0 measured from different scales and populations WILL NOT CONVERGE
- The spread in values will persist and may grow as more precise measurements reveal more of the underlying statistical structure
- Local measurements in gravitationally active regions will return higher values; large-scale measurements averaging over many environments will return lower values

The two long-established measurements, 67.4 km/s/Mpc from Planck CMB, and 73.04 km/s/Mpc from the SH_0ES distance ladder, define the current Hubble tension. Their systematic difference is consistent with the sorting framework's expectation that different methodologies sampling different populations and scales return different effective H_0 values. The specific physical interpretation offered in Table A1 is presented as a coherent interpretation consistent with the framework, not as a formally derived prediction. The non-convergence prediction is the strong claim.

Table A1. Measured H_0 Values and Their Interpretation Under the Sorting Framework

Method	**H_0 (km/s/Mpc)**	**Scale**	**Physical Regime**
Wagner group infall	63 ± 6	$z < 0.01$	Gravitationally bound group
Planck CMB	67.4 ± 0.5	$z \approx 1100$	Large-scale CMB average
SH0ES Cepheids	73.04 ± 1.04	$z < 0.15$	Peculiar velocity enhanced

Under the sorting framework, the three values are treated as measurements of an emergent statistical relationship whose effective value may depend on the population and scale sampled. Within base ΛCDM, the corresponding analyses are interpreted as constraints on a common H_0, subject to their respective modelling assumptions. The table therefore separates the measured values from the BFUT interpretation.

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