IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 10, June 2026
Impact Factor: 8.2

# Inter-Universal Transition Through Quantum Tunneling between Negative Cosmological Potential Wells

**Rawan Kumar[1], Neeraj Gupta[2], Rajinder Kumar[1]**
[1]Department of Physics, PSPS GCW Gandhi Nagar, Jammu, J&K
[2]Department of Physics, Govt. Degree College, Kathua, J&K
rawanphysics04@gmail.com and neerajalways@gmail.com

**Abstract:** *We propose a speculative cosmological framework in which individual universes are modeled as bound domains confined within negative potential wells embedded in a higher-dimensional meta-space. In this model, a universe $U_i$ is characterized by a potential depth, $V_i < 0$, while matter and radiation within the universe possess total energy E satisfying $V_i < E < 0$. This condition renders all physical systems bound states analogous to particles trapped inside finite quantum wells. Parallel universes are assumed to exist as neighboring minima separated by an inter-universal barrier of finite thickness. The possibility of transition between universes is investigated using analogies from quantum tunneling, vacuum decay, and higher-dimensional brane cosmology. The framework combines ideas inspired by the many-worlds interpretation [1], inflationary multiverse models [2,3], and vacuum tunneling mechanisms[4]. Although highly speculative and presently beyond experimental verification, the framework provides a mathematically suggestive toy model connecting quantum confinement, vacuum structure, and multiverse cosmology.*

**Keywords:** Multiverse, Quantum tunneling, Bound states, Negative potential wells, Vacuum structure, Higher-dimensional spacetime, Inter-universal transition.

## I. INTRODUCTION

The possibility that our observable universe may be only one among many universes has emerged in several branches of modern theoretical physics. The many-worlds interpretation introduced by Hugh Everett III[1] proposed that quantum measurement processes may lead to branching universal states. Subsequently, inflationary cosmology developed by Alan Guth [2] and extended by Andrei Linde[3] suggested that multiple causally disconnected universes may arise naturally through eternal inflation.

In parallel, higher-dimensional theories and brane-world models developed by Lisa Randall and Raman Sundrum[5] introduced the possibility that observable universes may exist as lower-dimensional manifolds embedded within higher-dimensional bulk spacetime. The present work proposes a complementary conceptual picture in which universes themselves behave as quantum bound states confined within negative cosmological potential wells.

In ordinary quantum mechanics, a particle confined inside a finite well satisfies

$$V < E < 0,$$

where V denotes the negative well potential. Such systems are spatially localized despite possessing nonzero kinetic energy. Motivated by this analogy, we hypothesize that: universes behave as metastable bound domains, matter and radiation correspond to bound excitations, neighboring universes are separated by finite barriers and inter-universal transfer may occur through tunneling-like processes.


DOI: 10.48175/IJARSCT-37283

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 10, June 2026
Impact Factor: 8.2

## II. COSMOLOGICAL POTENTIAL-WELL HYPOTHESIS

Consider a universe $U_i$ characterized by a negative confinement potential $V_1 < 0$. Matter and radiation within the universe possess total energy E satisfying

$$V_1 < E < 0.$$

This relation implies that physical systems remain energetically bound to the universe, analogous to localized quantum states inside finite potential wells.

Suppose another universe $U_2$ exists with potential depth $V_2 < 0$, separated by an inter-universal boundary of thickness d. The effective potential landscape may then be represented as:

$$V(x) = V1 \quad \text{for } x < 0$$
$$V(x) = V_b \quad \text{for } 0 < x < d$$
$$V(x) = V2 \quad \text{for } x > d$$

where $V_b$ denotes the barrier separating the universes. This structure resembles the double-well systems commonly studied in quantum mechanics and condensed matter theory.

## III. BOUND-STATE INTERPRETATION OF UNIVERSES

The wavefunction of a bound quantum system satisfies the time-independent Schrodinger equation:

$$-(\hbar^2/2m)\,\nabla^2\psi + V\,\psi = E\,\psi$$

For finite wells satisfying $V < E < 0$, the wavefunction decays exponentially inside classically forbidden regions but remains nonzero beyond the barrier. Consequently, finite tunneling probabilities emerge naturally. Inspired by the Hartle-Hawking wavefunction approach[6], we extend this interpretation to cosmology by introducing a generalized cosmological wavefunction describing universe localization within a larger meta-space.

## IV. INTER-UNIVERSAL QUANTUM TUNNELING

The phenomenon of quantum tunneling has been extensively studied in quantum mechanics and quantum field theory. In particular, vacuum tunneling processes analyzed by Sidney Coleman and Frank De Luccia[4] demonstrated that transitions between metastable vacuum states may occur through semiclassical tunneling.

Applying analogous reasoning to neighboring cosmological wells, the transmission probability between U1 and U2 may be approximated by:

$$T \approx e^{-2\kappa d}$$

where the decay constant κ is given by:

$$\kappa = \frac{\sqrt{2m(V_b - E)}}{\hbar}$$

## V. VACUUM STRUCTURE AND FALSE-VACUUM ANALOGY

Inflationary cosmology predicts that vacuum states may possess multiple metastable minima [2,3]. In quantum field theory, scalar field potentials V(φ) permit transitions between distinct vacuum configurations through tunneling processes [4].

Within the present framework, neighboring universes correspond to separate minima of a generalized cosmological vacuum potential. Inter-universal transport may therefore resemble localized vacuum-state transitions. Unlike conventional false-vacuum decay, the present model considers the speculative possibility of partial or localized transfer of physical systems rather than total vacuum conversion.

## VI. RESONANT BOUNDARY COUPLING

Quantum mechanical resonant tunneling systems demonstrate enhanced transmission when oscillatory states become frequency matched. Motivated by this phenomenon, we hypothesize that universes may possess characteristic vacuum oscillation frequencies $\omega 1$ and $\omega 2$. When these frequencies are approximately equal:

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 10, June 2026
Impact Factor: 8.2

$$\omega 1 \approx \omega 2$$

temporary enhancement of tunneling probability may occur through reduction of the effective barrier potential

$$V_b^{eff} < V_b.$$

Such resonance effects remain speculative but may provide a possible mechanism for transient inter-universal coupling.

## VII. HIGHER-DIMENSIONAL INTERPRETATION

Brane-world cosmology developed by Lisa Randall and Raman Sundrum [5] provides a geometrical interpretation of the proposed model. Inter-universal transfer would require sufficient energy to escape brane localization: $E_{escape} > E_{bulk.}$This interpretation naturally connects cosmological confinement with higher-dimensional geometry.

## VIII. PHYSICAL CONSTRAINTS

Several physical effects strongly suppress inter-universal transport. These constraints collectively render macroscopic or observable inter-universal transitions effectively impossible within the current framework.

### 8.1 Decoherence

Macroscopic systems rapidly undergo environmental decoherence, suppressing coherent tunneling amplitudes. Quantum coherence, a prerequisite for tunneling, is destroyed on timescales far shorter than any plausible inter-universal transition time.

### 8.2 Effective Mass Amplification

Since

$$\kappa \propto \sqrt{m}$$

large systems exhibit exponentially suppressed transmission probabilities. For any macroscopic object, the tunneling amplitude is suppressed by an astronomically large exponential factor.

### 8.3 Spacetime Coupling

Matter is dynamically coupled to the vacuum structure and geometry of its native universe. Separation from this native vacuum structure would require enormous energy densities.

### 8.4 Thermodynamic Stability

Cross-universal transfer may violate entropy constraints or destabilize vacuum equilibrium, introducing additional thermodynamic barriers beyond the quantum mechanical ones.

## IX. POSSIBLE OBSERVATIONAL IMPLICATIONS

Although presently unverifiable, the framework suggests several hypothetical signatures that could, in principle, arise from inter-universal coupling effects such as anomalous vacuum-energy fluctuations, weak gravitational leakage detectable through precision cosmological measurements, dark-sector interactions mediated through bulk propagation, transient nonlocal correlations in cosmological observables and cosmological energy anomalies inconsistent with standard single-universe models

Some of these ideas loosely parallel discussions concerning vacuum fluctuations and multiverse phenomenology in modern cosmology [2,3,6]

## X. CONCLUSION

We have proposed a speculative framework in which universes behave as negative-potential bound states embedded within a larger cosmological structure. Physical systems satisfy

$$V < E < 0,$$

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 10, June 2026
Impact Factor: 8.2

analogous to localized states inside finite quantum wells. Neighboring universes separated by finite barriers may admit exponentially suppressed transition probabilities through tunneling-like processes.

The framework combines ideas from quantum mechanics, vacuum decay theory, inflationary cosmology, and higher-dimensional physics. Although highly speculative, the model provides a mathematically suggestive perspective for discussing multiverse confinement and possible inter-universal dynamics. It is hoped that future developments in quantum gravity and cosmological theory may provide a more rigorous foundation for these ideas.

## REFERENCES

[1] Hugh Everett III, "Relative State Formulation of Quantum Mechanics," Reviews of Modern Physics, vol. 29, no. 3, pp. 454-462, 1957.

[2] Alan Guth, "Inflationary Universe: A Possible Solution to the Horizon and Flatness Problems," Physical Review D, vol. 23, pp. 347-356, 1981.

[3] Andrei Linde, "Eternally Existing Self-Reproducing Chaotic Inflationary Universe," Physics Letters B, vol. 175, pp. 395-400, 1986.

[4] Sidney Coleman and Frank De Luccia, "Gravitational Effects on and of Vacuum Decay," Physical Review D, vol. 21, pp. 3305-3315, 1980.

[5] Lisa Randall and Raman Sundrum, "Large Mass Hierarchy from a Small Extra Dimension," Physical Review Letters, vol. 83, pp. 3370-3373, 1999.

[6] Stephen Hawking and James Hartle, "Wave Function of the Universe," Physical Review D, vol. 28, pp. 2960-2975, 1983.

[7] Introduction to Quantum Mechanics, 2nd ed., Pearson Education, 2005.