

Feasibility of Observational Signatures for Dual Throat Wormholes Via Hawking-Radiation

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ABSTRACT

Wormholes are governed by theoretical observations reliant on astrophysical signatures that distinguish them from other phenomena, such as black holes. This paper features the investigation of the thermodynamic evolution of a dual throat wormhole by examining the Hawking-like radiation via the emission from the wormhole's inner (r_-) and outer (r_+) throats. This contention can be assessed through the lens of a modified version of the First Law of Thermodynamics, expressed as $dE = T_-dS_- + T_+dS_+$ (Keathley, 2022); through this modified First Law of Thermodynamics, both the inner and outer throat's thermodynamic systems can be accounted for. The initial part of the system represents the dynamical inner throat, while the second part of the system shows the outer throat's thermodynamics. Therefore, we can proceed to calculate the temperature gradients and energy transmissions across the two distinct geometries recognized as the inner and outer throats. We can further analyze this thesis by evaluating a heuristic model of two scenarios: an expanding inner throat and a contracting outer throat. The quantitative observations reveal a stark thermodynamic phase transition. The collapse of a wormhole varies in temperature and thermodynamic energy exchange ($\Delta E \rightarrow 0$) as the spatial gap between the throats narrows. The equilibrium at the extremal limit, where $r_+ = r_-$, effectively ceases all thermodynamic emission due to the wormhole collapsing. This study posits that the cessation of radiation has the capacity to serve as a distinct observational signature for a dual throat wormhole. By providing a clear differential idea between the dual throat spacetime and black hole evaporation, this investigation aims to demonstrate that thermodynamic limits offer a feasible and rigorous theoretical framework for future observational campaigns.

INTRODUCTION

It is established that wormholes differ from a standard Schwarzschild black hole. While black holes encompass an event horizon and undergo the fission caused by Hawking-Radiation over a longitudinal

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duration, theoretically creating macroscopic wormholes (Riken, 2022), the dual throat entity experiences a sudden and acute collapse, potentially into a black hole (Dimaschko, 2026). Nevertheless, the pursuit for the relative spacetime remains one of the most riveting explorations in general relativity quantum field theory. Despite numerous theoretical insights, distinguishing a distant wormhole from a standard black hole introduces significant observational challenges, due to both entities exhibiting abundant gravitational lensing and accretion disk dynamics (Dimaschko, 2026). A notable advantage, however, is that the thermodynamic properties of these geometries can inspire a potential indicative tool. Stephen Hawking's monumental discovery that black holes emit thermal radiation relies on the surface gravity at the event horizon (Page, 2005). According to Stephen Hawking, this process of thermal radiation leads to the evaporation of a standard black hole. The theory states that as the mass decreases, the temperature spikes until theoretical evaporation. Wormholes, particularly those including a dual throat geometry featuring an inner throat and an outer throat, add a layer of complexity to the thermodynamics. In principle, to map the energy dynamics of such a system, one can apply the First Law of Thermodynamics. Therefore, in this investigation, a modified version of the First Law of Thermodynamics ($dE = T_- dS_- + T_+ dS_+$) is applied that accounts for the distinct entropy and temperature changes at each respective throat.

As such, it is essential to ask regarding this topic: Can the investigation of Hawking-radiation, governed by a modified First Law of Thermodynamics, provide a feasible observational signature for dual throat wormholes? To attempt to answer this question, we computationally model the thermodynamic evolution of a dual throat wormhole through a heuristic model. Moreover, in this model, revised numbers are utilized due to the extensive thermodynamic capacities of the wormhole's throats. By analyzing the temperature and energy transfer of the spacetime as it approaches extremality ($r_+ = r_-$), we aim to demonstrate that dual throat wormholes can ultimately possess a radiative lifespan that possibly diverges from standard black hole observations.

METHODS

We begin the analysis with a general metric formula of

$$ds^2 = -f(r)dt^2 + \frac{1}{g(r)}dr^2 + r^2 d\Omega^2$$

Where $f(r) = e^{2\phi r}$ represents the redshift parameter, and $g(r) = 1 - \frac{b(r)}{r}$ represents the shape parameter. Furthermore, in this specific Reissner-Nordström wormhole model, these functions are defined as

$$\phi(r) = \frac{1}{2} \ln \left(\frac{(r-r_+)(r-r_-)}{r^2} \right)$$

$$b(r) = (r_+ + r_-) - \frac{r_+ r_-}{r}$$

Where r_+ is the outer throat, r_- is the inner throat, and r is the radial coordinate. The radial coordinate allows for the mapping needed for the physical geometry of the spacetime, and further acts as an independent variable to calculate the thermodynamic properties at distances throughout the wormhole tunnel.

We further assume that the wormhole is initially in a non-extremal state, progressing towards the extremal limit in the computational calculations; hence $r_+ > r_-$ for the duration of the analysis. Due to the initial state being non-extremal, we assume that the system operates at a non-zero temperature, where $T > 0$. This assumption ensures that the thermal radiation remains constant until the extremal limit and allows for the calculation of internal energy flux, dE .

Furthermore, we assume that the preconceived spacetime is charged, non-rotating, and spherically symmetric, ensuring that any thermodynamic changes are due to a shift in radial parameters rather than angular momentum.

All calculations are made using natural, arbitrary units, where the fundamental constants for gravity, the speed of light, and the Boltzmann constant are set to unity: $G = c = h = \kappa_B = 1$ (Page, 2005).

Thermodynamic Formulae

With the necessary foundations established, we can begin to analyze the thermodynamic properties of the throats. The surface gravity, κ , at each throat is derived from the standard metric surface gravity limit (B et al., 2024)

$$\kappa = \frac{1}{2} \frac{f'(r)}{\sqrt{f(r)/g(r)}}$$

Due to the metric components $f(r)$ and $g(r)$ both approaching zero at the throat ($r = r_{\pm}$), we can evaluate the term inside the square root using L'Hôpital's rule, where $\lim \frac{f(r)}{g(r)} = \frac{f'(r)}{g'(r)}$ (Kouba, 2016). Substituting this back into the limit's equation above yields the simplified version of the surface gravity equation

$$\kappa_{\pm} = \frac{1}{2} \sqrt{f'(r_{\pm})g'(r_{\pm})}$$

From this surface gravity, we calculate the semi-classical Hawking temperature, T , at the outer throat and inner throat respectively, using the standard relations

$$T_{+} = \frac{r_{+} - r_{-}}{4\pi r_{+}^2}$$

And

$$T_{-} = \frac{|r_{-} - r_{+}|}{4\pi r_{-}^2}$$

Furthermore, the entropy, S , in each throat follows the Bekenstein-Hawking area law by definition, where entropy is proportional to a quarter of the throat's surface area (Maldacena et al., 2023)

$$S_{\pm} = \frac{A_{\pm}}{4} = \pi r_{\pm}^2$$

Ultimately, the internal energy flux, dE , required to evolve the spacetime is governed by the modified First Law of Thermodynamics to accommodate for both the inner and outer throat (Keathley, 2022). It is represented as

$$dE = T_{+} dS_{+} + T_{-} dS_{-}$$

We trial the first scenario of the expanding inner throat by first isolating the dynamic inner throat, and treating the outer throat as a static boundary, where $dS_{+} = 0$. Hence, the equation in the first scenario simplifies to

$$dE = T_{-} dS_{-}$$

Contrariwise, when establishing the second scenario of the contracting outer throat, we isolate for the dynamic outer throat, allowing the inner throat to act as a static boundary, where $dS_- = 0$; formulating the equation to be

$$dE = T_+ dS_+$$

By differentiating both scenarios, we can begin to compare the thermodynamic energy required for the spacetime to reach the extremal limit via internal expansion, scenario one, versus external collapse, scenario two.

To isolate the thermodynamic evolution of the inner throat, we identify the outer throat as a static boundary by setting it to a constant of 10 arbitrary units. The numerical value of 10 is used to reduce the complexity of the heuristic model. We can then symmetrically vary the inner throat parameter (r_-), increasing its value until it approaches the extremal limit of the spacetime, where the throats merge, $r_+ \approx r_-$, ($r_- \rightarrow 10$).

r_+	r_-
10	0.5
10	1.1
10	1.8
10	2.9
10	3.9
10	4.8
10	5.9
10	7.1
10	8.4
10	9.9

In contrast, to isolate the thermodynamic evolution of the outer throat, we oppositely set the inner throat as the static boundary by setting it to a constant of 0.5 arbitrary units. The set value of 0.5 is established for the same justification as the previous constant. Once again, we proportionally vary the outer throat parameter (r_+), decreasing its value until it approaches the extremal limit of the spacetime; this is where the throats merge again through, $r_+ \approx r_-$, ($r_+ \rightarrow 0.5$).

r_-	r_+
0.5	10
0.5	9.4
0.5	8.6
0.5	7.6
0.5	6.5
0.5	5.3
0.5	4.0
0.5	2.6
0.5	1.1
0.5	0.6

ANALYSIS

We begin the analysis by first locating the coordinate boundaries of the spacetime by setting $g(r) = 0$. Expanding this yields the quadratic expression $(r - r_+)(r - r_-) = 0$, mathematically confirming that the structural throats of the wormholes are located at $r = r_+$ and $r = r_-$. With the boundaries confirmed, we can compute the thermodynamic evolution of spacetime under the two distinct dynamic scenarios; the expanding inner throat and contracting outer throat.

Dynamic Inner Throat

To initiate the computational analysis for scenario one, we first set the surface gravity limit using our symmetric metric components, where $f(r) = g(r)$. We start by determining the general radial derivative of the metric where

$$f'(r_{\pm}) = \frac{r_+ + r_-}{r_{\pm}^2} - \frac{2r_+ r_-}{r_{\pm}^3}$$

And

$$g'(r_{\pm}) = \frac{2r_+ - r_+ - r_-}{r_{\pm}^2}$$

Evaluating this derivative specifically at the inner throat of $r \rightarrow r_-$, yields a negative numerator, reflecting the surface gravity vector of the inner boundary

$$f'(r_-) = g'(r_-) = \frac{r_- - r_+}{r_-^2}$$

Substituting this derivative into the surface gravity limit resolves the ambiguous and negative form. Finally, to determine the semi-classical Hawking-temperature, we take the absolute value of the surface gravity to satisfy thermodynamic requirements

$$T_- = \frac{|\kappa_-|}{2\pi} = \frac{r_+ - r_-}{4\pi r_-^2}$$

Following the established computations, we calculate the thermodynamic outcome as the inner throat expands toward the outer boundary. The Hawking temperatures for the throats are detailed in Table 1.

Table 1: Evolution of surface gravity (κ), Hawking temperature (T), and entropy (S), as the inner throat expands toward the static outer boundary ($r_+ = 10$), $0.5 \leq r_- \leq 9$.

Inner Throat Value (r_-)	Inner Surface Gravity (κ_-)	Inner Temperature (T_-)	Inner Entropy (S_-)	Outer Surface Gravity (κ_+)	Outer Temperature (T_+)
0.5	19.00000	3.02394	0.78540	0.04750	0.00756
1.1	3.67769	0.58532	3.80133	0.04450	0.00708
1.8	1.26543	0.20140	10.17876	0.04100	0.00653
2.9	0.42212	0.06718	26.42079	0.03550	0.00565
3.9	0.20053	0.03191	47.78362	0.03050	0.00485
4.8	0.11285	0.01796	72.38229	0.02600	0.00414
5.9	0.05889	0.00937	109.35928	0.02050	0.00326
7.1	0.02876	0.00458	158.36768	0.01450	0.00231
8.4	0.01134	0.00180	221.67078	0.00800	0.00127
9.9	0.00051	0.00008	307.90705	0.00050	0.00008

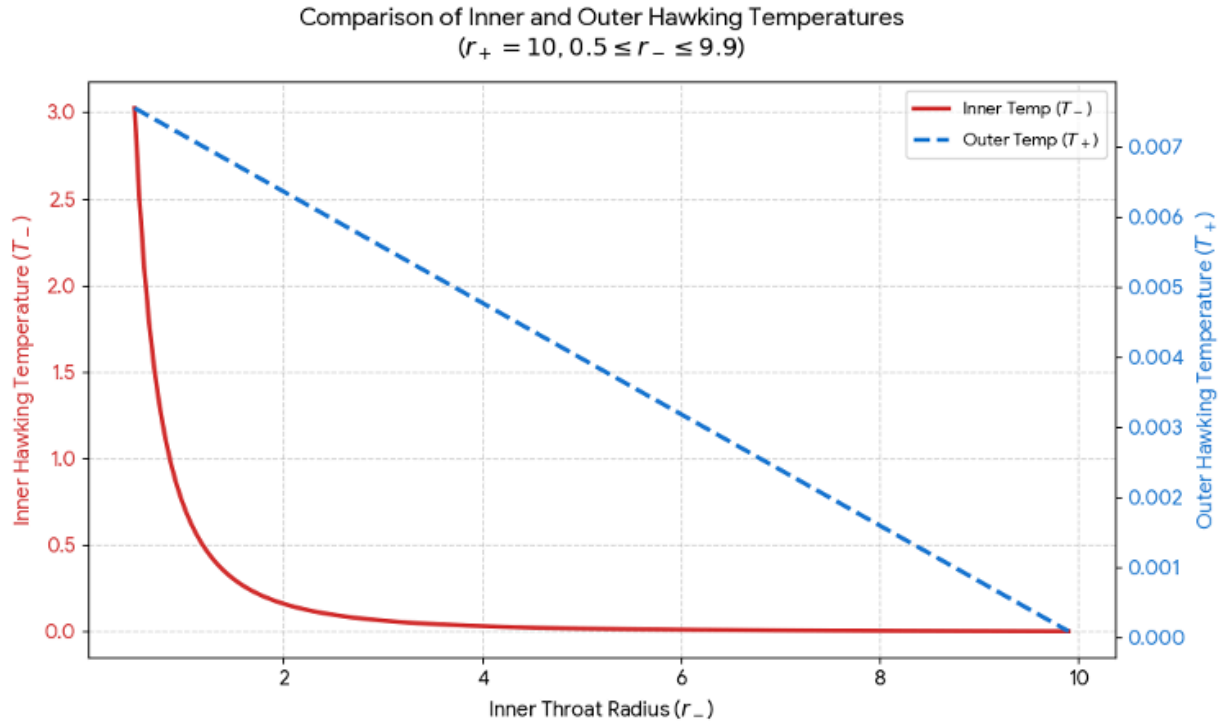


Figure 1: Comparison of the inner and outer throat Hawking temperatures (T_- and T_+) as the inner throat expands toward a static boundary ($r_+ = 10$).

As observed in the data above, when the inner throat approaches the extremal limit of 10, the Hawking temperatures of both throats trend towards absolute zero. This visually confirms that spacetime ceases to radiate and stabilizes completely when the throats merge.

Table 2: Thermodynamic energy evolution (ΔE) of the expanding inner throat, evaluated via the modified First Law of Thermodynamics ($dE = T_- dS_-$) for $0.5 \leq r_- \leq 9.9$, at a constant outer boundary of $r_+ = 10$.

Expanding Interval (r_-)	Entropy Change (ΔS_-)	Average Temperature ($T_{-,avg}$)	Energy Change (ΔE_-)
0.5 $\rightarrow$ 1.1	3.01593	1.80463	5.44264
1.1 $\rightarrow$ 1.8	6.37743	0.39336	2.50863
1.8 $\rightarrow$ 2.9	16.24203	0.13429	2.18116

2.9 → 3.9	21.36283	0.04955	1.05849
3.9 → 4.8	24.59867	0.02494	0.61343
4.8 → 5.9	36.97655	0.01367	0.50534
5.9 → 7.1	49.00885	0.00698	0.34186
7.1 → 8.4	63.30309	0.00319	0.20201
8.4 → 9.9	86.23672	0.00094	0.08131

Dynamic Outer Throat

Table 3: Thermodynamic properties of a dual throat wormhole during throat contraction. The data showcases the evolution of surface gravity (κ), Hawking temperature (T), and entropy (S) as the outer throat shrinks, $0.6 \leq r_+ \leq 10.0$, in relation to a static inner boundary $r_- = 0.5$.

Outer Throat (r_+)	Outer Surface Gravity (κ_+)	Outer Temperature (T_+)	Outer Entropy (S_+)	Inner Gravity (κ_-)	Inner Temperature (T_-)
10.0	0.04750	0.00756	314.15927	19.00000	3.02394
9.4	0.05036	0.00802	277.59113	17.80000	2.83296
8.6	0.05476	0.00872	232.35220	16.20000	2.57831
7.6	0.06146	0.00978	181.45839	14.20000	2.25997
6.5	0.07101	0.0113	132.73229	12.00000	1.90986
5.3	0.08544	0.0136	88.24734	9.600000	1.52789
4.0	0.1094	0.0174	50.26548	7.000000	1.11408
2.6	0.1553	0.0247	21.23717	4.200000	0.66845
1.1	0.2479	0.0395	3.80133	1.200000	0.19099
0.6	0.1389	0.0221	1.13097	0.200000	0.03183

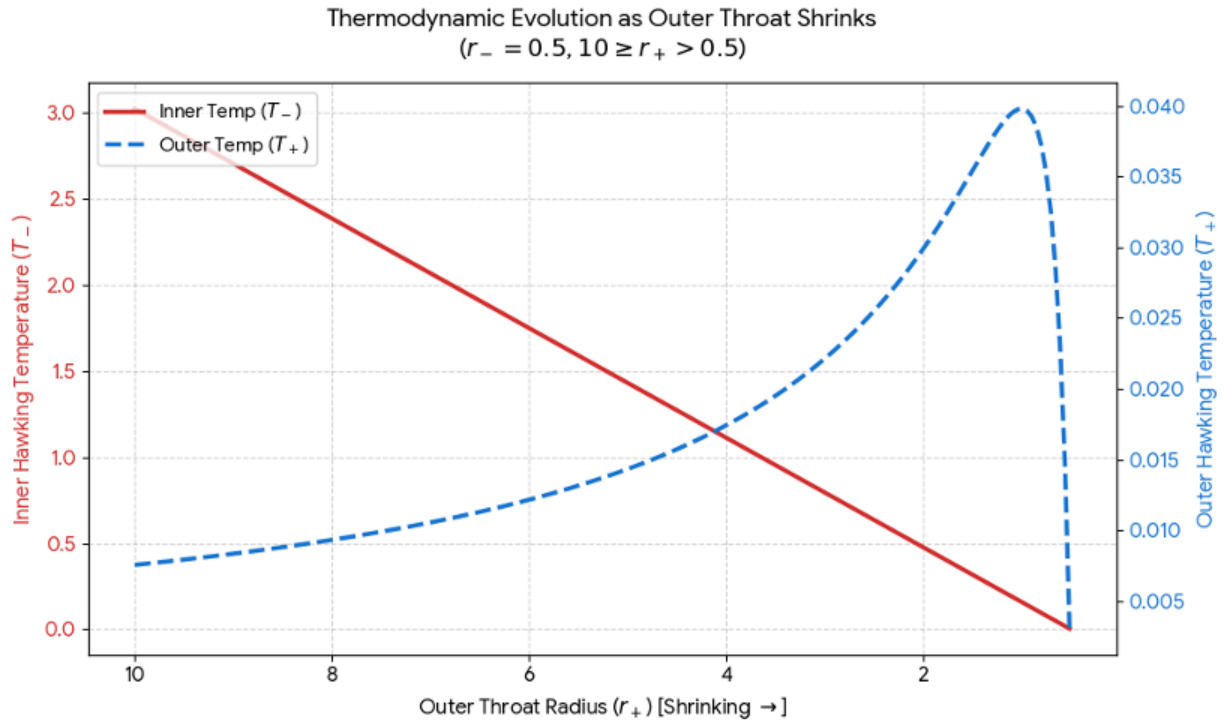


Figure 2: Dual axis plot illustrating the thermodynamic evolution of the inner (T_-) and outer (T_+) Hawking temperatures as the outer throat (r_+) shrinks towards a constant inner throat $(r_- = 0.5)$. Both temperatures converge to zero at the extremal limit.

As illustrated in figure 2 and table 3, the movement of the outer throat details a stark thermodynamic phase transition. While the inner throat temperature undergoes a portrayed linear decay, the outer throat temperature reaches a thermal peak, before evaporating to absolute zero. Initially, as r_+ shrinks, T_+ rises in a moderately exponential manner. This trend succeeds the expected characteristic of a standard black hole, which is a shrinking gravity surface, leading to a higher temperature. However, as the outer throat approaches the static inner boundary where $r_- = 0.5$, the surging heat discontinues almost instantaneously. The unexpected collapse of T_+ to absolute zero reflects the outcome of a scenario where the geometric proximity of the two boundaries $(r_+ \approx r_-)$ dominates the system, forcing the spacetime to promptly cease evaporation just before the boundaries merge at the extremal limit.

Table 4: Thermodynamic energy evolution (ΔE) of the contracting outer throat. Values are derived via the $dE = T_+ dS_+$, for the shrinking outer boundary ($10.0 \geq r_+ \geq 0.6$) in connection with the static inner throat ($r_- = 0.5$).

Shrinking Outer Boundary (r_+)	Entropy Change (ΔS_+)	Average Hawking Temperature ($T_{+,avg}$)	Energy Change (ΔE)
10.0 $\rightarrow$ 9.4	-36.5681	0.00779	-0.2849
9.4 $\rightarrow$ 8.6	-45.2389	0.00837	-0.3787
8.6 $\rightarrow$ 7.6	-50.8938	0.00925	-0.4708
7.6 $\rightarrow$ 6.5	-48.7261	0.0105	-0.5136
6.5 $\rightarrow$ 5.3	-44.4850	0.0125	-0.5538
5.3 $\rightarrow$ 4.0	-37.9819	0.0155	-0.5887
4.0 $\rightarrow$ 2.6	-29.0283	0.0211	-0.6113
2.6 $\rightarrow$ 1.1	-17.4358	0.0321	-0.5595
1.1 $\rightarrow$ 0.6	-2.67035	0.0308	-0.08219

DISCUSSION

In the first scenario, the model showed the thermodynamic yield of the system as the inner throat expands towards a constant outer boundary. The outer throat was locked at a static radius of $r_+ = 10$, yielding a constant entropy of ≈ 314.15927 . Since the outer boundary's spatial dimensions did not change, its discrete entropy was zero ($\Delta S_+ = 0$), meaning that the whole of the thermodynamic energy transfer occurred at the inner throat ($\Delta E_- = T_- dS_-$). The inner throat radius (r_-) was then mathematically expanded from the initial restricted state of 0.5, up to an approximate extremal limit of 9.9, deliberately stopping just short of $r_+ = r_-$. The expansion was modeled at specific intervals. The entropy change was calculated by finding the difference in boundary surface area and the average temperature was calculated to determine the energy transfer during that specific expansion phase.

In this second scenario, the inverse geometric evolution of the expanding inner throat was modeled to determine if the phase transition observed near extremality ($r_+ \approx r_-$) is symmetric. Here, the inner throat was locked at a static radius of $r_- = 0.5$. Consequently, although not explicitly calculated, the inner entropy remained constant, and all measurable thermodynamic energy transfer was transmitted to the shrinking outer boundary ($\Delta E_+ = T_+ \Delta S_+$). The outer throat radius was then modeled in a state of continuous contraction, beginning at 10.0 arbitrary units and shrinking down to 0.6 arbitrary units, approaching the extremal limit without crossing it ($0.6 \leq r_+ > 0.5$). Using identical computational steps to

scenario one allows for a clear demonstration of the symmetry of the dual throat geometry as it approaches the extremality point from both radial directions.

The quantitative results derived from both the expanding inner throat, (table 1, table 2, and figure 1) and the contracting outer throat (table 3, table 4, and figure 2) reveal a plausible distinction in thermodynamic mechanisms inherent to dual throat wormholes. To fully dissect the implications of these findings, it is necessary to comprehend the analysis of the findings against the mechanisms of a standard black hole, discuss the catalysts of the extremal limit, and explore the potential for actual astrophysical observation.

Deviation from Classical Schwarzschild Black Hole Evaporation

In standard General Relativity, the thermodynamic life cycle of a Schwarzschild black hole is defined by an inversely proportional relationship between its mass and temperature. When a classical black hole emits Hawking radiation, it loses mass; and as it loses mass, its surface area shrinks, causing its surface gravity and temperature to rise. This creates an unsolicited loop where in the final moments of a black hole's life, the classical model predicts a massive thermal spike. This spike is an explosive release of high-energy gamma radiation as the object evaporates completely (Federico & Profumo, 2025). Contrariwise, the dual throat object deviates from this classical understanding. Initially, the contraction of the outer throat (r_+) mimics the standard evaporation process. As r_+ decreases, the outer temperature, T_+ , rises steadily, suggesting that spacetime is heating up as its surface area shrinks. However, the presence of the dual throat, particularly the inner throat, causes the heat to abruptly discontinue as r_+ approaches r_- . Rather than resulting in an explosive thermal outcome, the geometry ends in a complete cessation of Hawking radiation. In figure 2, it can be observed that the inner temperature decreases in a linear slope until ceasing at the same point as the outer temperature, rather than initially increasing. This deviation can be further analyzed in figure 1, where the graph illustrates both the inner and outer temperatures as the outer throat expands towards a static boundary; hence, it can be deduced that the rate at which the inner temperature decreases is greater, due to its exponential relationship compared to the linear decrease for the outer temperature. In some respects, the temperatures decreasing for the inner throat follow some classical derivations, as it can be expected for the opposite relationships to occur between an expanding inner throat, versus a contracting outer throat. As such, it can be noted that the inner throat expanding results in both Hawking temperatures decreasing, at different rates, eradicating the classical predicted spike before evaporation.

A key limitation that presents itself is that the cessation of such an entity can occur expeditiously, making the examination of such a phenomenon extremely difficult. A manner in which we can circumvent this limitation is to conjure data of thermodynamic properties from across several hypothesized black holes and wormholes, such as their Hawking temperature, entropies, and surface gravities, and then extrapolate

the observed trends to hypothesize what each entity can be classified as, as done in the previous computations.

The Mechanism of the Extremal Limit and Energy Transfer

The math behind this phenomenon is established as a modified First Law of Thermodynamics, where $dE = T_- dS_- + T_+ dS_+$, which was applied to both throats. By calculating the discrete thermodynamic energy jumps (ΔE) across various space intervals, we observed a robust suppression of energy exchange near the extremal limit. In the first scenario where the inner throat expands, the initial thermal energy exchange is substantial. However, as the spatial gap between the two throats finalizes, the temperature T_- crashes in a strict, longitudinal direction towards absolute zero. Thus, the product of, $T_- \Delta S_-$, drops abruptly, yielding the small value of energy change of 0.08131. A mirrored effect is observed when the outer throat shrinks, where the evaporative energy loss accelerates initially but is rapidly ceased ($\Delta E = -0.08219$) in the final value before the extremality. Physically, this indicates that the proximity of the two throats forces the numerator of the surface gravity equation ($r_+ - r_-$) toward zero much faster than the shrinking radial denominator can expand it. The wormhole intrinsically reaches the extremal limit. By stopping its own energy radiation, the dual throat geometry avoids explosive evaporation.

A constraint in this contention is the inability for current technology to decipher such vast and instantaneous dissipations. This makes the monitoring of dual throat geometries extremely complex and unattainable. In an effort to preclude this restriction, we can leverage off of the extreme energy exchanges and adopt a tool which utilizes sensors to observe energy anomalies in its environment. To adequately work, these sensors would have to be spread over immense ranges to track the spacetime's energy jumps. This technology would also have to have the capability to observe smaller black holes and perceive their thermodynamic properties. It would also have to consider their fundamental attributes to establish whether they are the classical Schwarzschild, or if they are nascent wormholes.

Astrophysical Implications and Observational Signatures

The aforementioned stabilizing mechanism that the wormhole inherently establishes provides a moderately feasible outlook regarding the question of observational signatures emitted by wormholes. Currently, distinguishing a distant wormhole from a black hole using purely gravitational metrics, such as accretion disk luminosity and photon ring structures, is difficult due to extreme gravitational lensing overlaps (Tsukamoto et al., 2012). However, the thermodynamic lifespan of an object can provide a valuable diagnostic. If one were to observe and monitor the Hawking radiation lifespan of an evaporating, standard black hole, it would grow continuously hotter, bluer, and brighter, ending in an explosive burst. In contrast, a dual throat wormhole would potentially undergo a darkening phase. As it sheds mass and its throats converge, it would suddenly drop to absolute zero in a thermal perspective and go

thermodynamically dark. Therefore, prospective dual throat geometries exemplify the behaviour of a compact and gamma-ray void object; thus, having unacclimatized its thermodynamic environment to its mass. This stark thermal stabilization provides the potential to act as a highly specific astrophysical fingerprint. This can further provide evidence that analyzing thermodynamic limits is a highly feasible, and perhaps necessary, manner to observe and verify traversable wormhole candidates in our universe.

The rudimentary aspect of this implication is that this investigation would have to be a longitudinal study of an extremely prolonged duration for sufficient data to be collected, analyzed, and interpreted into a clear dissertation. If one were to examine a presumed classical Schwarzschild and analyze it to determine if it were an undetected wormhole with current infrastructures, it would take a significant amount of time to uncover the identity of the entity. In contrast, observing the energy jumps would also result in a prolonged study due to their existence in flashes. Therefore, designing a technology that consists of a matter composition identifier, an established thermodynamic discriminator from its coding, and a physical discerning feature would be instrumental in diagnosing what extreme the entity is transitioning towards; the two extremes being an explosive dissipation, or a slow fission.

CONCLUSION

In this study, we investigated the thermodynamic evolution of a dual throat wormhole to determine if its Hawking radiation profile could serve as a feasible observational signature. The endeavor for relative spacetime remains one of the most engaging explorations in general relativity quantum field theory; a reason being that dual throat wormholes could experience sudden and profound collapses, forming into a black hole (Dimaschko, 2026). This study was conducted by calculating the temperature gradients and applying a modified First Law of Thermodynamics, where $dE = T_- dS_- + T_+ dS_+$. This investigation further demonstrated that the interaction between an inner and outer throat prevents the evaporation that leads to an explosive end, such as that of a classical black hole. As the spatial distance between the two throats approaches zero ($r_+ \approx r_-$), the Hawking temperatures and thermodynamic energy exchange lead to an abrupt collapse to absolute zero. This absolute cessation of radiation provides the necessary means to contrast the mechanics of a standard black hole. As a result, we conclude that the sudden thermodynamic equilibrium of an evaporating compact object could indicate a viable and distinct astrophysical marker for identifying wormholes. Therefore, it is essential that future research focuses on integrating dynamic mass-loss computations, gravitational metrics, and quantum factors to determine the exact and precise timeframe of extremal positions.

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