BLACK HOLE AS ULTIMATE DECONFIGURATION OPERATOR: STAR ABSORPTION, EVENT HORIZON AND INFORMATION PARADOX THROUGH THE ODTOE LENS

Pankratov Anton Sergeevich

Independent researcher

E-mail: anton.s.pankratov@gmail.com

ORCID: 0009-0002-4870-2995

UDC 530.145 + 524.8 + 530.12

ABSTRACT

Within the Observer-Dependent Theory of Everything (ODTOE) [1], a reinterpretation of the nature of black holes is proposed. A black hole is shown to be not an "object curving spacetime" but an ultimate deconfiguration operator $\hat{D}$ whose action is inverse to the observation operator $\hat{O}$: while $\hat{O} : \mathcal{H} \to \mathcal{C}$ actualises configurations from the space of potential states, $\hat{D} : \mathcal{C} \to \mathcal{H}$ returns actualised configurations back to potentiality. The event horizon is interpreted as the boundary beyond which configuration inertia $I(C)$ becomes infinite for an external observer: reconfiguration inside the horizon is impossible from the outside, since $v = \alpha/(I + \varepsilon) \to 0$. Tidal disruption of a star (tidal disruption event, TDE) is formalised as a cascading deconfiguration: a highly coherent configuration C_{star} with $S \approx 1$ is disassembled into elementary constituents and returned to $\mathcal{H}$. The Hawking information paradox [2] is resolved naturally: information is not destroyed upon "falling" into a black hole — it returns to $\mathcal{H}$, where it existed originally and from where it can be re-actualised. Hawking radiation is interpreted as spontaneous re-actualisation: elements of $\mathcal{H}$ near the horizon are stochastically projected back into $\mathcal{C}$. Consequences for cosmology, quantum gravity and Event Horizon Telescope observations are discussed.

Keywords: black hole, event horizon, tidal disruption, deconfiguration, information paradox, Hawking radiation, coherence, ODTOE.

I. INTRODUCTION: WHAT IS A BLACK HOLE, REALLY?

Black holes are among the most extreme objects predicted by general relativity [3]. The Schwarzschild solution (1916) describes a region of spacetime from which nothing, including light, can escape: the gravitational radius $r_s = 2GM/c^2$ defines the event horizon — a "point of no return." Over the past century, black holes have evolved from a mathematical curiosity into an observational fact: the shadow image of the black hole M87* was obtained by the Event Horizon Telescope in 2019 [4], and gravitational waves from the merger of black holes were detected by LIGO in 2015 [5]. The 2020 Nobel Prize in Physics was awarded for theoretical and observational studies of black holes (Penrose, Genzel, Ghez), underscoring the central role of these objects in modern physics.

However, the fundamental nature of black holes remains a subject of debate. Three unsolved problems define the boundary of knowledge:

1. **Singularity.** GR predicts infinite curvature at the centre of a black hole — a point where the theory breaks down [3].
2. **Information paradox.** Hawking (1975) showed that black holes emit thermal radiation and ultimately evaporate [2]. If information about everything that fell into the hole is destroyed upon evaporation, the unitarity of quantum mechanics — one of its cornerstones — is violated [6].
3. **Firewall.** An attempt to reconcile information preservation with the semiclassical description of the horizon leads to the "firewall" paradox (Almheiri et al., 2013 [7]): the horizon is either smooth (GR) or incandescent (quantum mechanics), but cannot be both simultaneously.

ODTOE offers a way out of all three impasses by reformulating the very formulation of the question: a black hole is not an object *in* spacetime but a process of *deconfiguration* — the inverse act of observation. Information is not destroyed — it returns to the space of potential states $\mathcal{H}$, from which it was actualised by the observer. The horizon is not a physical barrier but the boundary of applicability of a particular observation operator $\hat{O}$. The singularity is not an infinity but a region of zero coherence where no description (including GR) holds any privilege.

The present work is organised as follows. In Section II, the deconfiguration operator $\hat{D}$ is introduced and the event horizon and singularity are interpreted. In Section III, tidal disruption of stars and quasi-periodic eruptions are considered. Section IV — the central one — is devoted to the information paradox and its resolution. In Section V, a systematic comparison with the classical approach is carried out. Section VI discusses cosmological consequences, including the Big Bang, dark energy and gravitational waves. In Section VII, experimentally testable predictions are formulated. Section VIII contains a discussion of limitations.

II. BLACK HOLE AS A DECONFIGURATION OPERATOR

II.1. The operator $\hat{D}$: inverse of $\hat{O}$

In ODTOE, reality is constituted by the observation operator [1]:

$$R = \hat{O}(\Psi), \quad \hat{O} : \mathcal{H} \to \mathcal{C} \tag{A.1}$$

The reverse injection $\iota : \mathcal{C} \to \mathcal{H}$ returns the result of observation to the space of potential states. In the ordinary self-observation cycle $\Phi = \iota \circ \hat{O}$, both operations occur sequentially and in balance: actualisation ($\hat{O}$) and return (ι) alternate.

The cycle Φ can be represented as a diagram:

$$\mathcal{H} \xrightarrow{\hat{O}} \mathcal{C} \xrightarrow{\iota} \mathcal{H} \xrightarrow{\hat{O}} \mathcal{C} \xrightarrow{\iota} \cdots \tag{II.0}$$

In ordinary reality this loop is closed and continuous: each act of observation generates a configuration that immediately returns to potentiality and can be actualised anew. A "loop break" refers to a situation in which one of the two links in the chain is suppressed. In the case of a black hole, $\hat{O}$ is suppressed: the injection ι operates (configurations return to $\mathcal{H}$), but re-actualisation is blocked for the external observer.

A black hole is a region where *only* the return dominates. We define the deconfiguration operator:

$$\hat{D} = \iota_{\text{lim}} : \mathcal{C} \to \mathcal{H}, \quad \text{without subsequent } \hat{O} \tag{II.1}$$

In the vicinity of a black hole, actualised configurations ($C \in \mathcal{C}$) irreversibly return to potentiality ($\Psi \in \mathcal{H}$), without passing through a new actualisation cycle. The loop Φ is *broken*: ι operates, while $\hat{O}$ does not (for the external observer).

Physically, the loop break means the following: an observer located outside the horizon cannot actualise configurations that have already been deconfigured by the operator $\hat{D}$. His operator $\hat{O}_{\text{ext}}$ has no access to those elements of $\mathcal{H}$ that have been "absorbed" by the black hole — not because they are destroyed, but because they lie outside the domain of definition of this particular $\hat{O}$.

It is important to emphasise the asymmetry: in ordinary physics there exist regions where observation is difficult (for example, the interior of a neutron star), but the cycle Φ is not broken — an external observer can, in principle, obtain information through electromagnetic or gravitational interaction. A black hole is unique in that the loop break is *absolute*: no process in $\mathcal{C}$ can deliver information from behind the horizon to the external $\hat{O}$. However, this restriction applies only to the $\mathcal{C}$ channel; the $\mathcal{H}$ channel (correlations in the space of potentiality) remains open — it is precisely this channel that ensures information preservation (see Section IV).

Formally, the operator $\hat{D}$ possesses the following properties that distinguish it from the ordinary injection ι:

- *Irreversibility for the external $\hat{O}$*: if $\hat{D}(C) = \Psi$, then $\hat{O}_{\text{ext}}(\Psi)$ is undefined — the external observer cannot re-actualise Ψ back into C.
- *Reversibility for the infalling $\hat{O}$*: the operator $\hat{O}_{\text{fall}}$ continues to function, and for it Ψ is available for actualisation. The loop Φ is not broken from its point of view.
- *Monotonicity*: $\hat{D}$ acts unidirectionally — from $\mathcal{C}$ to $\mathcal{H}$. An inverse operator $\hat{D}^{-1} : \mathcal{H} \to \mathcal{C}$ acting in the horizon region does not exist (for the external observer). This is the "point of no return."

II.2. The event horizon as an inertia boundary

The reconfiguration speed is determined by postulate P2 [1]:

$$v(C \to C') = \frac{\alpha}{I(C) + \varepsilon} \tag{P2.1}$$

At the event horizon, the configuration inertia for the external observer tends to infinity:

$$I(C)|_{r \to r_s} \to \infty \quad \Rightarrow \quad v \to 0 \tag{II.2}$$

Physical meaning: a configuration approaching the horizon "freezes" from the point of view of the external observer. This corresponds exactly to the prediction of GR: clocks near the horizon slow down to a complete stop for a distant observer [3].

The connection to the Schwarzschild metric can be established explicitly. The redshift factor in the Schwarzschild metric equals:

$$\sqrt{1 - \frac{r_s}{r}} \tag{II.2a}$$

This factor determines the ratio of proper time to coordinate time. In ODTOE, it corresponds to the ratio of inertia to the baseline inertia:

$$\frac{I_0}{I(C)} = \sqrt{1 - \frac{r_s}{r}} \tag{II.2b}$$

where I_0 is the configuration inertia at infinity. From this relation it follows:

$$I(C) = \frac{I_0}{\sqrt{1 - r_s/r}} \tag{II.2c}$$

As $r \to r_s$ the denominator vanishes and $I(C) \to \infty$, which reproduces formula (II.2). Thus, gravitational time dilation in GR is a *manifestation* of the configuration inertia gradient $I(C)$: the closer to the horizon, the higher the inertia and the slower the reconfiguration.

This result admits generalisation. For an arbitrary static spherically symmetric spacetime with metric $ds^2 = -f(r)c^2dt^2 + f(r)^{-1}dr^2 + r^2d\Omega^2$, the configuration inertia is:

$$I(C) = \frac{I_0}{\sqrt{f(r)}} \tag{II.2d}$$

The horizon ($f(r_s) = 0$) automatically corresponds to $I \to \infty$. For the Reissner–Nordström metric (charged black hole) $f(r) = 1 - r_s/r + r_Q^2/r^2$, yielding two horizons (outer and inner) — two boundaries where $I \to \infty$. Between them the inertia is finite: $\hat{D}$ acts, but the loop Φ can be partially restored. This is consistent with the well-known GR result that the inner Reissner–Nordström horizon is unstable (mass inflation) — in ODTOE: the region of the "restored loop" between horizons is configurationally unstable.

However, ODTOE adds an essential clarification: for the *infalling* observer, the inertia is not infinite. His own operator $\hat{O}_{\text{fall}}$ continues to function, actualising configurations. The paradox of the two viewpoints (external and infalling) is resolved through the observer-dependence of $I(C)$: inertia is a property of the pair "configuration + operator," not of the configuration by itself.

This is consistent with one of the deepest results of GR: the equivalence principle. Locally, in a freely falling frame, gravity "disappears" — and in ODTOE this means that $I(C)$ for a freely falling observer remains finite and continuous. Einstein's equivalence principle is reformulated in ODTOE as: *configuration inertia depends on the choice of the observation operator*. For every observer there exists a reference frame in which $I(C) = I_0$ locally — this is "free fall."

II.3. The singularity as $S = 0$

The GR singularity — a point of infinite curvature — is interpreted in ODTOE as a region where the system's coherence vanishes:

$$S|_{r\to 0} = 0 \tag{II.3}$$

By the formula for the number of simultaneous theories (P6) [1]:

$$N_{\text{theories}} = N_0 \cdot (1 - S)^m + 1$$

at $S = 0$: $N_{\text{theories}} = N_0 + 1 \to \infty$. In the "singularity" there exist infinitely many simultaneously valid descriptions — no theory holds any privilege. This is precisely why GR "breaks" at the singularity: it is one among infinitely many descriptions, and its predictions (infinite curvature) reflect not physical reality but the limit of applicability of a given configuration.

II.4. Cosmic censorship and naked singularities

The Penrose cosmic censorship hypothesis [18] states that singularities are always hidden behind an event horizon — "naked" singularities do not exist in nature. Within ODTOE, this hypothesis receives a natural justification.

The region $S = 0$ (singularity) is a region of maximal indeterminacy where infinitely many descriptions are simultaneously valid. If such a region were accessible to an external observer (naked singularity), his operator $\hat{O}$ would have to "choose" one description from an infinite set — but no selection criterion exists (all are equivalent). This means that actualisation from the region $S = 0$ is impossible for any particular $\hat{O}$:

$$\hat{O}(\Psi)|_{S=0} = \text{undefined} \tag{II.4}$$

The indeterminacy of $\hat{O}$ at $S = 0$ automatically requires the presence of a boundary $I(C) \to \infty$ between the observer and the region of zero coherence — that is, an event horizon. Thus, cosmic censorship is not an additional postulate but a consequence of the structure of ODTOE: the observer cannot actualise what is in principle non-actualisable.

Note that this argument also explains why “naked singularities” (even if they exist as mathematical solutions of Einstein’s equations) are physically unobservable. A region $S = 0$ without a horizon would mean the accessibility of infinitely many descriptions to a single observer — which is equivalent to the impossibility of *any* description. An observer “seeing” a naked singularity sees nothing definite. This is not a prohibition but a tautology: the infinitely indeterminate cannot be determined.

For rotating black holes (Kerr metric) the situation is more complex: the internal structure contains a ring singularity and a region with closed timelike curves. In ODTOE, this corresponds to a region where not only $S = 0$ but coherence acquires *imaginary* values — the configuration “twists” into a loop, closing the cycle Φ onto itself. A detailed analysis of rotating black holes lies beyond the scope of the present work, but we note that the Kerr ergosphere is interpreted as a region where $\hat{D}$ acts *partially*: configurations are not fully deconfigured but are forced to “rotate” — to reconfigure in the direction of the black hole’s rotation.

III. TIDAL DISRUPTION OF A STAR: CASCADING DECONFIGURATION

III.1. Classical description

When a star approaches a supermassive black hole to within the tidal radius $r_t \approx R_*(M_{BH}/M_*)^{1/3}$ [8], tidal forces exceed the star’s self-gravity and it is disrupted. Approximately half of the material is captured by the black hole, and half is ejected. The process is accompanied by a powerful flare in the optical, ultraviolet and X-ray bands, lasting from weeks to months. The light curve is characteristically described by a power-law decay $L \propto t^{-5/3}$, predicted from the theory of accretion of returning material onto the black hole. By 2025, approximately 100 such events have been detected [9], including AT2024tvd — the first discovered TDE from a wandering black hole outside the galactic centre [10].

Observational data on TDEs have been significantly enriched in recent years. The ZTF (Zwicky Transient Facility) survey and the future LSST (Legacy Survey of Space and Time) increase the TDE detection rate to tens of events per year. The typical peak luminosity of a TDE is $L_{\text{peak}} \sim 10^{43}$–$10^{45}$ erg/s, comparable to quasar luminosities. TDE spectra display broad hydrogen lines (Hα, Hβ) and helium lines (He II), as well as strong ultraviolet and soft X-ray emission. The TDE rate in a typical galaxy is estimated at $\sim 10^{-4}$–10^{-5} events per year [9]. The spectral evolution of TDEs follows a characteristic pattern: the initial “blue” phase (dominance of UV and soft X-ray) gives way to a “red” phase (optical and infrared), reflecting the gradual cooling of the accretion flow.

III.2. Interpretation through ODTOE

A star is a highly coherent configuration: $S_{\text{star}} \approx 1$ (atoms are coordinated into a single self-sustaining process). The lifetime is determined by formula P3 [1]:

$$T(C_{\text{star}}) = \frac{T_0}{(1 - S_{\text{star}})^n} \to \infty \tag{III.1}$$

Tidal disruption is a process of *cascading deconfiguration*: the black hole's operator $\hat{D}$ "disassembles" the coherent configuration into its constituents, returning them to $\mathcal{H}$:

$$C_{\text{star}} \xrightarrow{\hat{D}} C_{\text{debris}} \xrightarrow{\hat{D}} C_{\text{elem}} \xrightarrow{\hat{D}} \Psi \in \mathcal{H} \tag{III.2}$$

At each stage, coherence drops: $S_{\text{star}} \to S_{\text{debris}} \to S_{\text{elem}} \to 0$. Each drop in S is accompanied by energy release — this is how the TDE flare arises. The flare energy is proportional to the *change in coherence*:

$$E_{\text{TDE}} \propto \Delta S \cdot M_* c^2 \tag{III.3}$$

Let us estimate the energy budget. For a typical solar-type star ($M_* \approx M_\odot$), the total rest energy is $M_\odot c^2 \approx 1.8 \times 10^{54}$ erg. If $\Delta S \sim 0.01$–0.1 (a typical range of coherence loss at the first stage of the cascade), the flare energy is:

$$E_{\text{TDE}} \sim (0.01\text{–}0.1) \cdot M_\odot c^2 \sim 10^{52}\text{–}10^{53}\ \text{erg} \tag{III.3a}$$

The observed total energy of TDEs is $\sim 10^{51}$–10^{52} erg [9]. The order-of-magnitude difference is explained by the fact that only a fraction of the deconfiguration energy is radiated in the electromagnetic band; the rest is carried away by the kinetic energy of the ejected material and neutrinos.

Note that formula (III.3) predicts a dependence of TDE energy on the *type* of disrupted star. A more coherent star (compact, high-density — a white dwarf with $S_{\text{WD}} \approx 0.99$) should produce a more powerful flare than a diffuse star (a red giant with $S_{\text{RG}} \approx 0.7$), since ΔS upon disruption of a compact star is larger. Observational data are consistent with this picture: TDEs from dense stars (if the black hole is small enough to disrupt them outside the horizon) exhibit a harder spectrum and higher peak luminosity [9].

The cascading character of deconfiguration (III.2) also predicts a characteristic *temporal* structure of TDE luminosity. The first stage ($C_{\text{star}} \to C_{\text{debris}}$) is fast, seconds to minutes: tearing the star into streams of material. The second stage ($C_{\text{debris}} \to C_{\text{elem}}$) is slower, days to weeks: formation of an accretion disc and its "digestion." The third stage ($C_{\text{elem}} \to \Psi$) is the slowest, months to years: final deconfiguration of elementary constituents. This explains the observed TDE light curve: rapid rise, peak, and then slow power-law decay $L \propto t^{-5/3}$ [9].

III.3. Why the flare occurs *outside*, not inside

A paradoxical observational fact: the TDE flare occurs not at the horizon but at a considerable distance from it. The classical explanation: the accretion disc is heated by friction. ODTOE offers an additional explanation: deconfiguration begins long before the horizon, since the gradient of $\hat{D}$ decreases with distance but is nonzero already at $r \gg r_s$.

Analogy: a coherent structure (star) begins to "come unglued" upon approaching the region of $\hat{D}$ dominance, just as the order of ice is disrupted long before the melting temperature is reached — through surface premelting.

Quantitatively: the deconfiguration gradient $\nabla\hat{D}$ can be estimated as:

$$|\nabla\hat{D}| \propto \frac{dI(C)}{dr} = \frac{I_0 r_s}{2r^2\left(1 - r_s/r\right)^{3/2}} \tag{III.3b}$$

At $r \gg r_s$: $|\nabla\hat{D}| \propto r_s/r^2$ — small but nonzero. Tidal disruption begins when $|\nabla\hat{D}| \cdot R_* > S_{\text{bond}}$, where S_{bond} is the minimum coherence holding the star together as a whole. This condition is equivalent to the classical tidal criterion $r < r_t$, but expressed in the language of coherence rather than in the language of forces.

III.4. Delayed radio jets

In October 2025, it was discovered that powerful radio outflows from TDEs arise *months* after the disruption of the star [11]. In ODTOE: the return of a configuration to $\mathcal{H}$ is not instantaneous but a cascading process. High-inertia configurations (heavy nuclei, magnetic fields) are deconfigured later than light ones (hydrogen). The delay of radio jets reflects the *inertia hierarchy*: $I(C_{\text{magn}}) > I(C_{\text{hydrogen}})$.

III.5. Quasi-periodic eruptions (QPE)

Quasi-periodic eruptions (QPE) are a recently discovered observational phenomenon: repeating X-ray flares with periods from several hours to a day, originating from galactic nuclei [19]. QPEs have been detected in several sources (GSN 069, RX J1301.9+2747, eRO-QPE1, eRO-QPE2, etc.) and are presumably associated with repeated interaction of a star or compact object with an accretion disc around a supermassive black hole.

In ODTOE, quasi-periodic eruptions are interpreted as *repeated partial deconfiguration*. If a star is on an elongated orbit around a black hole, it enters the domain of action of the operator $\hat{D}$ at each pericentre passage but is not fully absorbed. At each passage, coherence is partially reduced:

$$S_{\text{star}}^{(n+1)} = S_{\text{star}}^{(n)} - \delta S(r_{\text{min}}) \tag{III.4}$$

where $\delta S(r_{\text{min}})$ is the coherence loss per passage, depending on the minimum distance to the black hole. Each drop δS is accompanied by an X-ray flare with energy:

$$E_{\text{QPE}} \propto \delta S \cdot M_{\text{shell}} c^2 \tag{III.5}$$

where M_{shell} is the mass of the shell lost per passage. The periodicity of QPEs is determined by the orbital period, and the decay of the flare series by the gradual exhaustion of coherence: when $S^{(n)}_{\text{star}} \to 0$, the star is fully deconfigured and the flares cease.

ODTOE prediction: the energy of successive QPE flares should decrease (each subsequent δS is smaller since the coherence has already been reduced), and the spectrum should soften (low-coherence configurations are deconfigured at lower energies). Preliminary data on GSN 069 are consistent with this picture [19].

Interestingly, QPEs represent a "laboratory" for studying deconfiguration: unlike a full TDE, where the process is completed in a single episodic flare, QPEs allow one to observe *step-by-step* deconfiguration in real time. Measuring the successive values of flare energy and spectrum allows reconstruction of the dependence $\delta S(S)$ — the functional form of the operator $\hat{D}$ near a particular black hole. This is one of the most promising routes for experimental verification of the ODTOE description of black holes.

IV. INFORMATION PARADOX: RESOLUTION

IV.1. The essence of the paradox and the history of resolution attempts

Hawking (1975) showed: a black hole emits thermal radiation of temperature $T_H = \hbar c^3/(8\pi G M k_B)$ [2]. If the hole completely evaporates, where did the information about everything that fell into it go? Thermal radiation carries no information (by definition of a thermal spectrum). Therefore, information is destroyed — but this violates the unitarity of quantum mechanics [6].

Hawking's argument can be stated step by step:

1. Quantum field theory on a curved background predicts that the vacuum state near the horizon is unstable: virtual particle–antiparticle pairs are created at the horizon; one particle falls inside, the other escapes to infinity.
2. The escaping particles form a thermal spectrum with temperature T_H, proportional to the surface gravity of the horizon. A thermal spectrum is maximally entropic — it carries no information about the state from which it arose.
3. The black hole loses mass through this radiation and ultimately evaporates completely.
4. After complete evaporation, neither the black hole nor information about what fell into it remains — only thermal radiation. A pure quantum state has turned into a mixed one — unitarity is violated.

Formally, the problem is expressed as follows. Let the initial state be pure: $|\psi\rangle = |\psi_{\text{matter}}\rangle \otimes |0_{\text{vacuum}}\rangle$. After evaporation, the final state is mixed: $\rho_{\text{final}} = \sum_i p_i |\phi_i\rangle\langle\phi_i|$. But in unitary quantum mechanics, a pure state cannot evolve into a mixed one: $|\psi\rangle\langle\psi| \xrightarrow{U} U|\psi\rangle\langle\psi|U^\dagger$ — again pure. Therefore, either quantum mechanics is wrong (Hawking's position until 2004) or the radiation is not strictly thermal (the position of most theorists). ODTOE shows a third way: the contradiction arises from a mistaken identification of "information" with "configuration in $\mathcal{C}$."

The paradox was sharpened in 1993 when Preskill [6] made a bet with Hawking (known as the "Preskill–Hawking–Thorne bet"): is information preserved during evaporation? In 2004, Hawking conceded, acknowledging that AdS/CFT arguments convinced him of information preservation — however, the *specific mechanism* was never identified.

Over half a century, a number of resolution attempts have been proposed. Let us consider the main ones.

Black hole complementarity (Susskind, 1993). Leonard Susskind, Larus Thorlacius and John Uglum proposed the principle of complementarity [20]: information simultaneously exists both inside the horizon (from the infalling observer's perspective) and outside it (on the stretched horizon, from the external observer's perspective). The two descriptions never come into conflict since no single observer has access to both simultaneously.

Problem: complementarity is a *postulate*, not a derivation from a fundamental theory. Moreover, the AMPS argument [7] showed that complementarity is incompatible with monogamy of entanglement (see Section IV.5).

Holographic principle ('t Hooft, 1993). Gerard 't Hooft proposed that all information about a three-dimensional volume can be encoded on its two-dimensional boundary [21]. For a black hole, this means that information about everything that fell in is encoded on the event horizon (whose area determines the Bekenstein–Hawking entropy $S_{BH} = A/(4l_P^2)$).

Problem: the holographic principle describes *where* information is stored but does not explain *how* it is returned during evaporation. The encoding and decoding mechanism remains unclear.

AdS/CFT correspondence (Maldacena, 1997). Juan Maldacena showed [22] that quantum gravity in anti-de Sitter (AdS) space is mathematically equivalent to conformal field theory (CFT) on its boundary. Since CFT is unitary, the process of black hole evaporation in AdS must also be unitary.

Problem: AdS/CFT is a partial resolution, applicable only to spaces with a negative cosmological constant. Our Universe has a positive cosmological constant (de Sitter), and direct generalisation of AdS/CFT to dS space remains an open problem. Furthermore, AdS/CFT proves unitarity but does not indicate the specific mechanism of information escape.

Page curve (Page, 1993). Don Page showed [23] that if black hole evaporation is unitary, the entanglement entropy between the radiation and the black hole first increases (while the black hole is large), reaches a maximum approximately midway through evaporation (the Page time), and then decreases to zero — when the hole has fully evaporated, the radiation is in a pure state.

Problem: the Page curve describes *what* should happen if unitarity is preserved but does not explain *how* it happens. Hawking's semiclassical calculation gives monotonically increasing entropy — a contradiction with the Page curve. Recent works (Penington, 2019; Almheiri, Engelhardt, Marolf, Maxfield, 2019) showed that accounting for "islands" — special regions inside the horizon — makes it possible to reproduce the Page curve within semiclassical gravity. However, the island formulae rely on not entirely justified assumptions about the gravitational functional integral and work explicitly only in two-dimensional or AdS gravity.

Each of these attempts makes an important contribution, but none offers a complete mechanism: complementarity is a postulate without derivation; the holographic principle describes encoding but not decoding; AdS/CFT works only in a special spacetime; the Page curve describes the result but not the process.

In addition to those listed, there exist a number of other approaches: remnant states (remnants), "soft hair" (Hawking, Perry, Strominger, 2016), island formulae (island rule) for entropy, related to gravitational path integral calculations. Each of these approaches adds important elements, but none provides a closed solution outside the framework of special theoretical assumptions (AdS space, two-dimensional gravity, topological simplifications).

ODTOE proposes a different approach: rather than seeking a mechanism for "returning information from the hole," it shows that information *was never in the hole*. The paradox is not resolved — it *dissolves*, being a consequence of a false initial premise.

IV.2. Resolution through ODTOE

In ODTOE, information is not "contained" in a configuration $C \in \mathcal{C}$ — it *is the structure* of $\mathcal{H}$ [12]. A configuration is a projection from $\mathcal{H}$, not a container of information. When a configuration is deconfigured by the operator $\hat{D}$ and "falls" into a black hole, the corresponding element $\Psi \in \mathcal{H}$ *is not destroyed*. It returns to the state in which it existed prior to actualisation.

$$\hat{D}(C) = \iota(C) = \Psi \in \mathcal{H} \tag{IV.1}$$

The information paradox arises from the assumption that information "resides" in $\mathcal{C}$ and can be "destroyed" upon transition to a state where $\mathcal{C}$ is inaccessible (horizon). But in ODTOE, $\mathcal{H}$ is primary, $\mathcal{C}$ is secondary. Destroying information is impossible because information is not a property of the screen ($\mathcal{C}$) but a property of the film ($\mathcal{H}$) [12].

IV.2a. The key ontological shift: information lives in $\mathcal{H}$, not in $\mathcal{C}$

The Hawking information paradox implicitly assumes *configurational realism*: the belief that physical reality is identical to the configuration space $\mathcal{C}$, while $\mathcal{H}$ is merely a mathematical abstraction. In this paradigm, "falling into a black hole" means destruction of information, since the configuration C ceases to exist in $\mathcal{C}$.

ODTOE performs an ontological shift: $\mathcal{H}$ is the fundamental space, and $\mathcal{C}$ is a projection. Information is the *structure of connections* in $\mathcal{H}$, not a property of a configuration in $\mathcal{C}$. A configuration C is a temporary actualisation, a "snapshot" of some aspect of $\mathcal{H}$. Destroying the snapshot does not destroy what it depicts.

Analogy: a film projected onto a screen (= $\mathcal{C}$) exists on the filmstrip (= $\mathcal{H}$). If the screen goes dark (= the horizon absorbs the configuration), the filmstrip is unharmed. The information paradox is equivalent to the assertion "if the screen went dark, the film is destroyed" — this is a category error [12].

This ontological shift has precedents in the history of physics. The transition from Newtonian mechanics to GR required a shift from absolute space to dynamical spacetime. The transition from classical physics to quantum physics required a shift from determinism to probability amplitudes. ODTOE requires an analogous shift: from "reality is $\mathcal{C}$" to "reality is $\mathcal{H}$, and $\mathcal{C}$ is its projection." Each such shift does not refute the previous theory but shows that it described a projection rather than the fundamental structure.

Consequence of the ontological shift for black holes: the question "where did the information go upon falling into a black hole?" is just as ill-posed as the question "where did the wave function go upon measurement?" in the Copenhagen interpretation. In both cases, the question presupposes that what "disappeared" existed in the same space as the observer. In ODTOE: the wave function (= element of $\mathcal{H}$) does not "disappear" upon measurement (= actualisation) — it is projected into $\mathcal{C}$. Similarly, information does not "disappear" upon falling into a black hole — it is deconfigured back into $\mathcal{H}$.

IV.2b. Formal proof of information preservation

Let us show that the operator $\hat{D}$ preserves information. Information is defined as the structure of $\mathcal{H}$ — the set of connections between elements $\Psi_i \in \mathcal{H}$. The operator $\hat{D} = \iota_{\lim}$ is the reverse injection returning $C \in \mathcal{C}$ to $\Psi \in \mathcal{H}$.

Claim. If the injection $\iota : \mathcal{C} \to \mathcal{H}$ is an injective mapping (i.e. $\iota(C_1) = \iota(C_2) \Rightarrow C_1 = C_2$), then the deconfiguration operator $\hat{D}$ does not destroy information.

Proof. Information in ODTOE is defined as the structure of $\mathcal{H}$. The operator $\hat{D}$ maps $C \mapsto \Psi = \iota(C)$. Since ι is injective, distinct configurations are mapped to distinct elements of $\mathcal{H}$:

$$C_1 \neq C_2 \quad \Rightarrow \quad \iota(C_1) \neq \iota(C_2) \tag{IV.1a}$$

Therefore, $\hat{D}$ does not "glue" distinct configurations into a single point in $\mathcal{H}$. Each configuration deconfigured by the black hole leaves a unique "imprint" in $\mathcal{H}$. Information about the distinction between C_1 and C_2 is preserved in $\mathcal{H}$ even after both configurations have been absorbed by the horizon.

Moreover, the injectivity of ι is not an additional postulate but a consequence of the definition of ι as the inverse mapping of $\hat{O}$. If $\hat{O}$ actualises distinct elements of $\mathcal{H}$ into distinct configurations (which is necessary for observation to be meaningful), then the inverse mapping is automatically injective.

Formally:

$$\hat{O} \text{ is surjective onto } \mathrm{Im}(\hat{O}) \quad \Rightarrow \quad \iota = \hat{O}^{-1}|_{\mathrm{Im}(\hat{O})} \text{ is injective} \qquad \text{(IV.1b)}$$

Thus, preservation of information under deconfiguration is not a postulate of ODTOE but a *theorem* following from the structure of the theory. □

IV.2c. Comparison with the holographic principle and ER=EPR

The resolution of the information paradox through ODTOE can be compared with the two most influential approaches.

The holographic principle [21] states that information is encoded on a two-dimensional surface (horizon). In ODTOE, information is not encoded on the horizon — it exists in $\mathcal{H}$, which is neither a surface nor a volume but a space of potential states. The holographic principle is valid as an *approximation*: since the horizon is the boundary $I(C) \to \infty$, the number of configurations accessible to the external observer is bounded by the horizon area (via the Bekenstein–Hawking formula). However, this bound pertains to $\mathcal{C}$, not to $\mathcal{H}$: in potentiality, information is not bounded by area.

The ER=EPR conjecture (Maldacena, Susskind, 2013) [24] proposes that every pair of entangled particles is connected by an Einstein–Rosen bridge (wormhole). For a black hole: the Hawking radiation particles are connected to the interior through microscopic wormholes, ensuring coherence and information preservation.

In ODTOE, ER=EPR receives a natural interpretation: the “wormhole” is a connection through $\mathcal{H}$. Entangled particles are correlated not through a spatial “bridge” in $\mathcal{C}$ but through a common source in $\mathcal{H}$. The two descriptions (ER=EPR and ODTOE) are compatible, but ODTOE is more fundamental: it explains *why* entanglement and geometry are related — because both are projections of the structure of $\mathcal{H}$ into $\mathcal{C}$.

Comparison of three approaches to information preservation:

Aspect	Holography	ER=EPR	ODTOE
Where is information?	On the horizon (2D)	In wormholes	In $\mathcal{H}$
Exit mechanism	Not defined	Through ER bridges	Re-actualisation from $\mathcal{H}$
Firewall	Problematic	Removed	Removed
Domain of applicability	Any black hole	Requires AdS/CFT	Any system
Status	Empirical	Conjecture	Consequence of ontology

IV.3. Hawking radiation as spontaneous re-actualisation

Hawking radiation in ODTOE is *stochastic re-actualisation* of elements of $\mathcal{H}$ near the horizon. The stochastic noise $D(\eta) = D_0(1 - S)$ [1] near the horizon ($S \to 0$) is maximal: $D(\eta) \to D_0$. This means that fluctuations are large, and with finite probability elements of $\mathcal{H}$ spontaneously actualise into $\mathcal{C}$ — "pop out" of potentiality.

The Hawking temperature in ODTOE is related to the stochastic noise at the horizon:

$$T_H \propto D(\eta)|_{\text{horizon}} = D_0(1 - S_{\text{horizon}}) \tag{IV.2}$$

At $S_{\text{horizon}} \to 0$: $T_H \propto D_0$ — maximal "noisiness," maximal temperature (for small black holes). At $S_{\text{horizon}} \to 1$ (a hypothetical "coherent" black hole): $T_H \to 0$ — no radiation.

Let us consider the re-actualisation mechanism in more detail. In standard quantum field theory on a curved background, Hawking radiation is explained through the creation of virtual particle–antiparticle pairs near the horizon. One member of the pair falls inside the horizon (negative energy), the other escapes to infinity (positive energy). This entire process is described within $\mathcal{C}$.

In ODTOE, the mechanism is fundamentally different. Near the horizon, coherence $S \to 0$ and the stochastic noise $D(\eta) \to D_0$ is maximal. Elements $\Psi \in \mathcal{H}$ — potential states — fluctuate. With finite probability $p \propto D(\eta)$, an element Ψ *spontaneously actualises*:

$$\Psi \in \mathcal{H} \xrightarrow{D(\eta)} C \in \mathcal{C} \tag{IV.2a}$$

The re-actualised configuration C ends up outside the horizon (since actualisation occurs in a region accessible to the external $\hat{O}$) and is registered as a Hawking radiation particle.

The key difference from the standard mechanism: in ODTOE there is no "virtual pair," one member of which "falls inside." There is a single process: an element of $\mathcal{H}$, previously deconfigured by the black hole, spontaneously re-actualises outside. This explains why re-actualised particles *carry correlations*: they arise from the same $\Psi \in \mathcal{H}$ that was deconfigured and retain connections with other elements of $\mathcal{H}$ through the non-separability of the space of potentiality.

The re-actualisation probability can be estimated. Let Γ_{react} be the re-actualisation rate per unit area of the horizon. In ODTOE:

$$\Gamma_{\text{react}} \propto D(\eta)|_{\text{horizon}} \cdot \rho_{\mathcal{H}} \tag{IV.2b}$$

where $\rho_{\mathcal{H}}$ is the density of elements of $\mathcal{H}$ near the horizon (the number of deconfigured elements per unit "area" in $\mathcal{H}$). For a black hole of mass M, the horizon area is $A = 16\pi G^2 M^2/c^4$, and the total radiation power is:

$$P_H = \Gamma_{\text{react}} \cdot A \cdot \langle E_{\text{particle}} \rangle \tag{IV.2c}$$

where $\langle E_{\text{particle}} \rangle \sim k_B T_H$ is the mean energy of a re-actualised particle. Substituting $T_H \propto 1/M$ and $A \propto M^2$ gives $P_H \propto 1/M^2$ — exactly Hawking's formula for the radiation power. Thus, the stochastic re-actualisation mechanism quantitatively reproduces Hawking's result but with a different physical interpretation.

An additional consequence: since re-actualisation is stochastic rather than deterministic, the radiation spectrum contains *noise* beyond the thermal component. This noise is not interference but an information carrier: fluctuations in the spectrum reflect correlations between elements of $\mathcal{H}$. Detection of a characteristic "informational noise" in the Hawking spectrum (distinguishable from thermal noise) would be an experimental confirmation of ODTOE.

IV.4. Does Hawking radiation carry information? The Page curve in ODTOE

In the standard formulation — no (thermal spectrum). In ODTOE — *yes*, but in encoded form. Spontaneously re-actualised elements $\Psi \in \mathcal{H}$ carry correlations with the original configuration, since $\mathcal{H}$ is non-separable: elements that were part of a single configuration C_{star} preserve entanglement through the entropy formula [13]:

$$S(\rho_{\text{int}}) = -\text{Tr}(\rho_{\text{int}} \log \rho_{\text{int}}) > 0 \tag{IV.3}$$

Information "exits" the black hole not through a classical channel but through correlations in $\mathcal{H}$ — the same mechanism as in quantum entanglement [14].

The Page curve [23] — the dependence of entanglement entropy of the radiation on time — is naturally reproduced in ODTOE. Let us consider the evaporation of a black hole stage by stage.

Early stage (black hole mass $M \gg M_{\text{Pl}}$). The horizon is large, coherence at the horizon $S_{\text{horizon}} \approx 0$. Stochastic re-actualisation produces particles weakly correlated with one another: each particle arises from "its own" element of $\mathcal{H}$, and connections between elements are not yet manifest. The radiation spectrum is close to thermal. The entanglement entropy between radiation and the black hole grows:

$$S_{\text{entang}}(t) \approx S_{\text{BH}}(t) \quad \text{for } t \ll t_{\text{Page}} \tag{IV.3a}$$

Page time (the black hole mass has decreased by approximately half). The number of re-actualised elements of $\mathcal{H}$ is comparable to the number remaining. Correlations between previously emitted and not-yet-emitted particles become significant — the non-separability of $\mathcal{H}$ begins to manifest. The entanglement entropy reaches its maximum:

$$S_{\text{entang}}^{\text{max}} = S_{\text{BH}}(t_{\text{Page}}) \approx \frac{1}{2} S_{\text{BH}}(0) \tag{IV.3b}$$

Late stage (black hole mass $M \to 0$). The black hole is small; most elements of $\mathcal{H}$ have already been re-actualised. Each newly re-actualised particle is strongly correlated with those already emitted — correlations in $\mathcal{H}$ are "uncovered." The radiation increasingly deviates from the thermal spectrum. The entanglement entropy decreases:

$$S_{\text{entang}}(t) \to 0 \quad \text{for } t \to t_{\text{evap}} \tag{IV.3c}$$

After complete evaporation $S_{\text{entang}} = 0$ — the radiation is in a pure state. Unitarity is preserved.

Thus, the Page curve in ODTOE is not a postulate and not the result of complex calculations in AdS/CFT, but a direct consequence of the non-separability of $\mathcal{H}$: at early stages correlations are hidden; at late stages they are manifest.

IV.5. The firewall paradox and its resolution

The firewall paradox (AMPS) [7] is one of the sharpest challenges to black hole physics. Let us consider it in detail.

Almheiri, Marolf, Polchinski and Sully (2013) showed that three generally accepted postulates are mutually incompatible:

1. **Unitarity**: information is preserved during evaporation (the process is described by an S-matrix).
2. **Semiclassicality outside**: quantum field theory on a curved background correctly describes the physics outside the horizon.
3. **Equivalence**: the infalling observer experiences nothing special upon crossing the horizon (equivalence principle of GR).

The AMPS argument can be stated step by step:

1. Suppose the black hole is older than the Page time. Previously emitted radiation (R_{early}) is in a pure state entangled with the remaining part of the black hole (BH): $S(R_{\text{early}}) = S(BH)$.
2. Consider a newly emitted particle b and its "partner" behind the horizon $\tilde{b}$. The semiclassical calculation requires that b and $\tilde{b}$ be maximally entangled (Unruh vacuum state).
3. Unitarity requires that b be entangled with R_{early} (otherwise entropy does not decrease).
4. Monogamy of entanglement: b cannot be maximally entangled simultaneously with $\tilde{b}$ and with R_{early}.
5. Therefore, the entanglement b–$\tilde{b}$ must be broken, which implies a high-energy state at the horizon — a firewall.

The equivalence principle is violated: the infalling observer encounters a "wall of fire" upon crossing the horizon.

Resolution in ODTOE. The AMPS paradox arises within configurational realism — the assumption that all physics takes place in $\mathcal{C}$. In that case, the horizon is a physical surface in $\mathcal{C}$, and the "partner behind the horizon" is a real configuration with which entanglement must be maintained.

In ODTOE, the horizon is not a physical surface but the boundary of the domain of definition of a particular $\hat{O}$. It is the boundary $I(C) \to \infty$, i.e. a boundary of *observability*, not a physical barrier. The "partner behind the horizon" does not exist as a configuration in $\mathcal{C}$ — it has been deconfigured and returned to $\mathcal{H}$.

The three AMPS postulates are reformulated:

1. **Unitarity**: preserved automatically — information is in $\mathcal{H}$ and $\hat{D}$ is injective (IV.2b).
2. **Semiclassicality**: valid in $\mathcal{C}$ where $S > 0$. Near the horizon, $S \to 0$ and the semiclassical approximation ceases to be exact.
3. **Equivalence**: preserved for the infalling observer — his $\hat{O}_{\text{fall}}$ encounters no barrier since $I(C)$ is finite for him.

The conflict is removed because ODTOE *rejects* the implicit AMPS premise: that the "partner behind the horizon" $\tilde{b}$ is a configuration in $\mathcal{C}$. In reality, $\tilde{b}$ is an element of $\mathcal{H}$, deconfigured by the operator $\hat{D}$. Monogamy of entanglement is a theorem of quantum mechanics applicable to states in $\mathcal{C}$ (the Hilbert space of standard quantum theory). But $\mathcal{H}$ is not the Hilbert space of quantum mechanics; it is a space of potential states with a different (richer) structure of connections. Monogamy of entanglement in $\mathcal{C}$ imposes no constraints on correlations between elements of $\mathcal{C}$ and $\mathcal{H}$.

In other words: particle b (in $\mathcal{C}$) can be simultaneously correlated with R_{early} (in $\mathcal{C}$) *and* with $\tilde{b}$ (in $\mathcal{H}$), since the second type of correlation is not "entanglement" in the standard quantum-mechanical sense but a *connection through potentiality* — a different kind of connection that does not obey monogamy.

Thus, the firewall does not exist: the horizon is smooth for the infalling observer, information is preserved for the external observer, and monogamy of entanglement is not violated since one of the "entangled sides" is not in $\mathcal{C}$ but in $\mathcal{H}$.

Let us summarise the resolution of the firewall paradox in tabular form:

AMPS postulate	Standard conflict	Status in ODTOE
Unitarity	Requires correlations in radiation	Satisfied: $\hat{D}$ is injective
Semiclassicality outside	Requires thermal spectrum	Approximation at $S > 0$; breaks down at $S \to 0$
Equivalence at the horizon	Incompatible with firewall	Satisfied: $I(C)$ is finite for the infalling observer
Monogamy of entanglement	Forbids double entanglement	Not applicable: one side is in $\mathcal{H}$, not in $\mathcal{C}$

V. DIFFERENCES FROM THE CLASSICAL VIEW

V.1. Summary table

Aspect	GR + QM (classical)	ODTOE
A black hole is...	A region of spacetime with extreme curvature	A region of $\hat{D}$ dominance — the deconfiguration operator
The horizon is...	A surface from which light cannot escape	The boundary $I(C) \to \infty$ for the external $\hat{O}$
The singularity is...	A point of infinite curvature (theory breakdown)	A region $S = 0$: infinitely many descriptions, none privileged
Information upon falling...	Paradox: destroyed? preserved?	Returns to $\mathcal{H}$, whence it was actualised
Hawking radiation...	Thermal, carries no information	Spontaneous re-actualisation from $\mathcal{H}$ with correlations
TDE (star absorption)...	Tidal disruption + accretion	Cascading deconfiguration $C_{\text{star}} \to \Psi \in \mathcal{H}$
Firewall...	Paradox: smooth or incandescent?	Does not arise: horizon is a boundary of $I(C)$, not a physical barrier
Spacetime...	Fundamental, curved by mass	Configuration at $S \to 1$; near a hole $S \to 0$ — geometry loses meaning

V.2. Key conceptual difference

Classical physics views a black hole as an object that *destroys* structure. ODTOE views a black hole as a process that *returns* structure to potentiality. Destruction and return are fundamentally different concepts:

- Destruction is irreversible and leads to information loss.
- Return is reversible (in principle) and preserves information in $\mathcal{H}$.

Analogy: an ice sculpture melts. From the sculptor's perspective — destruction (the form is lost). From the water's perspective — a return to the liquid state (the molecules are the same; information about the bonds is preserved in potentiality; the water can be frozen into a sculpture again). A black hole "melts" configurations back into the "water" of $\mathcal{H}$.

VI. COSMOLOGICAL CONSEQUENCES

VI.1. The Big Bang as the inverse process

If a black hole is a deconfiguration operator ($\mathcal{C} \to \mathcal{H}$), then the Big Bang is the ultimate configuration operator ($\mathcal{H} \to \mathcal{C}$): a mass actualisation from potentiality. The Universe is born as an act of observation of maximal scale [15].

Black holes and the Big Bang are two poles of a single process: configuration ↔ deconfiguration. The Universe breathes: $\mathcal{H} \xrightarrow{Big\ Bang} \mathcal{C} \xrightarrow{Black\ Holes} \mathcal{H}$.

In ODTOE, the initial state of the Universe corresponds to $S = 0$ — a state of maximal potentiality and zero coherence. All configurations reside in $\mathcal{H}$; none is actualised. The number of simultaneous descriptions $N_{\text{theories}} \to \infty$ — no theory applies (hence the Big Bang "singularity" in GR: the theory breaks down because it is one among infinitely many).

The inflationary stage [15] in ODTOE is interpreted as a *wave of rapid actualisation*: the transition from $S = 0$ to $S > 0$ is accompanied by an exponential growth in the number of actualised configurations. The "inflation" of space is a consequence of mass actualisation: each new configuration "occupies a place" in $\mathcal{C}$, expanding it:

$$\frac{d|\mathcal{C}|}{dt} \propto \frac{dS}{dt} \cdot N_{\text{potent}} \tag{VI.1}$$

where $|\mathcal{C}|$ is the "volume" of configuration space (an analogue of the scale factor), and N_{potent} is the number of elements of $\mathcal{H}$ available for actualisation. At $S \approx 0$, virtually all elements are available and the expansion rate is maximal — exponential inflation. As S grows, the number of "free" elements decreases, and the expansion slows to a power law (standard Friedmann cosmology).

The end of inflation (reheating) in ODTOE is the moment when the primordial configurations achieve sufficient coherence to form stable structures (elementary particles, nuclei). At this moment, S crosses a critical value S_{crit} at which the configuration lifetime (by formula P3) becomes macroscopic. Before this moment, configurations "flicker" — they actualise and deconfigure too rapidly for a stable world to form. After $S > S_{\text{crit}}$, they stabilise and ordinary cosmological evolution begins.

Remarkably, in this picture the thermal equilibrium of the early Universe (the horizon problem) is resolved naturally: at $S \approx 0$, all elements of $\mathcal{H}$ are connected (non-separability), and correlations between distant regions are not the result of causal contact but a property of the space of potentiality.

VI.2. The black hole as a configuration "recycler"

In ecology there is the concept of material cycling: from inorganic → to organic → back. In ODTOE, black holes perform an analogous function for configurations: they return "spent" configurations to $\mathcal{H}$, freeing the "potentiality resource" for new actualisations. A Universe without black holes would "clog up" with outdated configurations of high inertia.

This analogy can be formalised. Define the *configurational balance* of the Universe:

$$\frac{d|\mathcal{C}|}{dt} = \Gamma_{\text{actual}} - \Gamma_{\text{deconf}} \tag{VI.1a}$$

where Γ_{actual} is the actualisation rate (creation of new configurations by observers) and Γ_{deconf} is the deconfiguration rate (return of configurations by black holes). In steady state $\Gamma_{\text{actual}} \approx \Gamma_{\text{deconf}}$, and the "volume" of $\mathcal{C}$ is stable. The growth in the number of black holes over time (as galaxies evolve) increases Γ_{deconf}, which may compensate for the growth of Γ_{actual} from the increasing number of observers. This dynamic equilibrium is a cosmological analogue of homeostasis.

VI.3. Why black holes are at the centres of galaxies

Supermassive black holes (10^6–$10^{10} M_\odot$) have been found at the centres of virtually all large galaxies [16]. In ODTOE: the centre of a galaxy is the region of maximal observer density (stars). Maximal collective coherence P_{coll} [1] creates the maximal gradient $\nabla U(C)$ — and, consequently, the maximal reconfiguration speed. A black hole is a "dump point": the deconfiguration flow is directed to where the configurational pressure is maximal.

VI.4. Dark energy as potentiality pressure

The accelerated expansion of the Universe, discovered in 1998 [25], is explained in standard cosmology by introducing a cosmological constant Λ or dark energy — a component with negative pressure. The nature of dark energy remains one of the great puzzles of physics.

ODTOE proposes the following interpretation (speculative but formally grounded). The space of potentiality $\mathcal{H}$ "exerts pressure" on the configuration space $\mathcal{C}$. Non-actualised elements of $\mathcal{H}$ tend towards actualisation — this creates an effective pressure expanding $\mathcal{C}$:

$$P_{\mathcal{H}} \propto |\mathcal{H}| - |\mathcal{C}| = N_{\text{potent}} - N_{\text{actual}} \tag{VI.2}$$

Since $|\mathcal{H}| \gg |\mathcal{C}|$ (potential states vastly outnumber actualised ones), the pressure is always positive and leads to expansion. This explains the observed properties of dark energy:

- *Constancy in time*: $|\mathcal{H}|$ changes very little (the return of configurations through black holes compensates for actualisation), so $P_{\mathcal{H}} \approx \text{const}$ — an analogue of the cosmological constant.
- *Smallness*: $P_{\mathcal{H}}$ is determined by the *difference* $|\mathcal{H}| - |\mathcal{C}|$, which for $|\mathcal{H}| \to \infty$ and $|\mathcal{C}| \to \infty$ can be finite and small — this explains the anomalous smallness of the cosmological constant ($\Lambda \sim 10^{-122}$ in Planck units).

- *Negative pressure*: in standard cosmology, dark energy has an equation of state $w = p/\rho \approx -1$. In ODTOE, the potentiality pressure $P_{\mathcal{H}}$ acts not as ordinary material pressure (compression) but as a “pushing apart” of configurations — expansion of $\mathcal{C}$. This naturally corresponds to $w < 0$.

Testable consequence: if dark energy is related to the pressure of $\mathcal{H}$, its density should be related to the deconfiguration rate (black hole activity) in the observable Universe. Epochs of high AGN (active galactic nuclei) activity should correlate with changes in the expansion rate — though the effect may be too small for detection by current instruments.

This interpretation is speculative and requires quantitative development. However, it illustrates the productivity of the ODTOE framework: a fundamental puzzle (the nature of dark energy) receives a conceptually clear explanation. If this interpretation is correct, dark energy is not an exotic substance and not a property of the vacuum but a manifestation of the fundamental asymmetry between $\mathcal{H}$ and $\mathcal{C}$: potentiality is always “greater” than actuality, and this excess manifests as expansion.

VI.5. Gravitational-wave astronomy: black hole mergers as composition of $\hat{D}$ operators

LIGO/Virgo/KAGRA observations [5] have registered dozens of black hole merger events. In GR, a merger is described as the process of unification of two horizons into one, accompanied by gravitational wave emission and mass-energy loss.

In ODTOE, the merger of two black holes is a *composition* of two deconfiguration operators:

$$\hat{D}_{\text{merger}} = \hat{D}_1 \oplus \hat{D}_2 \to \hat{D}_{12} \tag{VI.3}$$

The combined operator $\hat{D}_{12}$ is not a simple “sum” of the originals: during the merger, some configurations previously deconfigured by $\hat{D}_1$ and $\hat{D}_2$ individually are “released” — re-actualised. This released configurational energy constitutes the gravitational waves.

The merger process can be decomposed into three phases (in accordance with the observed gravitational waveform):

- *Inspiral*: the two operators $\hat{D}_1$ and $\hat{D}_2$ interact at a distance. Their domains of action overlap, and configurations between them experience “double deconfiguration” — accelerated return to $\mathcal{H}$. This corresponds to the increasing amplitude and frequency of gravitational waves (chirp).
- *Merger*: the domains of action fully overlap, forming a single $\hat{D}_{12}$. The restructuring of the boundary $I(C) \to \infty$ is accompanied by maximal release of configurational energy — the peak of the gravitational wave signal.
- *Ringdown*: the combined $\hat{D}_{12}$ “settles down” — its boundary $I(C) \to \infty$ acquires a stationary form (Kerr horizon). The oscillating quasi-normal modes are a relic of operator restructuring.

Gravitational radiation during a merger:

$$E_{\text{GW}} \propto (I(\hat{D}_1) + I(\hat{D}_2) - I(\hat{D}_{12})) \cdot c^2 \tag{VI.4}$$

where $I(\hat{D})$ is the "inertia" of the deconfiguration operator (an analogue of the black hole mass). The loss of inertia during the merger corresponds to the observed fact: the mass of the combined black hole is less than the sum of the masses of the originals (the difference is radiated as gravitational waves). For the event GW150914, this difference amounted to $\sim 3M_\odot \cdot c^2 \approx 5.4 \times 10^{54}$ erg [5].

ODTOE predicts that the gravitational wave signal from a merger contains information not only about masses and spins (as in GR) but also about the *coherence* of the merging deconfiguration regions. Third-generation detectors (Einstein Telescope, Cosmic Explorer) may be sensitive enough to test this prediction [26].

Besides binary black hole mergers, gravitational-wave astronomy observes black hole–neutron star and binary neutron star mergers. In ODTOE, the merger of a neutron star with a black hole is a process in which a highly coherent configuration ($S_{\text{NS}} \approx 1$) is absorbed by the operator $\hat{D}$. Unlike a TDE (where the star is disrupted at a great distance), a neutron star is a far more compact and coherent object, and deconfiguration occurs directly near the horizon. The gravitational wave signal should carry the imprint of this "final" deconfiguration: an abrupt termination of tidal interaction, reflecting the transition $S \to 0$. The cutoff frequency is related to the neutron star size and can be used to measure the nuclear matter equation of state — one of the key goals of gravitational-wave astronomy [5].

Of separate interest are extreme mass-ratio inspirals (EMRI): a low-mass compact object (neutron star or stellar black hole) orbiting a supermassive black hole. The LISA detector (launch planned in the 2030s) will be sensitive precisely to such systems. In ODTOE, an EMRI is a "slow deconfiguration": the small object slowly approaches the domain of $\hat{D}$ dominance of the supermassive black hole, and its coherence decreases on each orbital revolution. The gravitational wave signal of an EMRI carries information about the radial profile of $\hat{D}$ — effectively, about the form of the function $I(C, r)$ — which makes it possible to test formula (II.2c) with high precision.

VII. EXPERIMENTALLY TESTABLE PREDICTIONS

1. **Correlations in Hawking radiation.** ODTOE predicts that Hawking radiation is not strictly thermal but contains correlations reflecting the structure of $\mathcal{H}$. Detection of such correlations (deviation from the Planck spectrum) would confirm the prediction. Practically: analysis of the spectrum of isolated black holes with sensitivity currently unavailable is required [2].

2. **Hierarchy of delays in TDEs.** Formula (III.2) predicts that elements with different inertia are deconfigured at different rates. Heavy elements (iron, nickel) should display a delay in the TDE spectrum relative to light ones (hydrogen, helium). The observation of delayed radio jets [11] is consistent with this prediction.

3. **Dependence of T_H on the coherence of the environment.** Formula (IV.2) predicts that a black hole in a highly coherent environment (near a compact star cluster, $S_{\text{env}} > 0$) should have a *lower* effective Hawking temperature than an isolated black hole. Verification requires comparison of spectral characteristics of black holes in dense and sparse environments.

4. **Ring structure of the shadow.** If the horizon is the boundary $I(C) \to \infty$, then near the horizon a *gradient* structure (gradual increase of I) should be observed rather than a sharp boundary. EHT images [4] show precisely such a picture: a blurred ring rather than a sharp edge.

5. **Decay of QPE series energy.** Formulae (III.4) and (III.5) predict that the energy of successive quasi-periodic flares from a single source should decrease monotonically and the spectrum should soften. A systematic analysis of eROSITA data and future ATHENA observations can test this prediction [19].

6. **Gravitational-wave "coherence memory."** Formula (VI.4) predicts that the gravitational wave signal from a black hole merger contains fine structure related to the coherence of the deconfiguration regions. This may manifest as a deviation from GR predictions in the ringdown phase, detectable by third-generation detectors [26].

7. **Profile of $I(C, r)$ from EMRI data.** Gravitational-wave observations of extreme mass-ratio inspiral (EMRI) systems by the LISA detector will allow reconstruction of the radial profile of configuration inertia $I(C, r)$ near supermassive black holes and comparison with the prediction of formula (II.2c).

8. **Dark energy and AGN activity.** If dark energy is related to potentiality pressure (formula VI.2), its effective density should (weakly) correlate with the total black hole activity in the Universe. Epochs of high AGN activity (peak at $z \sim 2$) should be accompanied by a measurable (though probably small) change in the expansion rate. Verification requires precision cosmological data (DESI, Euclid, Roman Space Telescope).

VIII. DISCUSSION AND LIMITATIONS

1. *The operator $\hat{D}$ is not formally defined.* Formula (II.1) introduces $\hat{D}$ as a "limiting ι," but a rigorous mathematical definition (domain of definition, continuity properties, spectrum) requires further development.

2. *Connection to GR.* Formula (II.2) asserts $I(C) \to \infty$ at the horizon. A formal derivation of this limit from the Einstein equations within ODTOE has not been carried out. It is necessary to establish the exact mapping between $I(C)$ and the metric tensor $g_{\mu\nu}$.

3. *Observational limitations.* Hawking radiation for astrophysical black holes ($M \gg M_\odot$) is unobservably small ($T_H \sim 10^{-8}$ K for $M = M_\odot$). Verification of the predictions of Section VII is possible only for extremely small black holes or through analogue models [17].

4. *Status of "return" to $\mathcal{H}$.* The assertion that deconfiguration "returns" information to $\mathcal{H}$ rests on the ontological status of $\mathcal{H}$ as a fundamental space. If $\mathcal{H}$ is merely a mathematical construction (instrumentalist position), "return" loses physical meaning.

5. *Quantitative predictions.* A number of formulae in the present work (II.2b, III.3a, VI.2) contain undetermined proportionalities ($\propto$) or order-of-magnitude estimates. For a fully predictive theory, it is necessary to derive exact coefficients from the first principles of ODTOE, which requires deeper mathematical development.

6. *Rotating and charged black holes.* The present work focuses on non-rotating uncharged black holes (Schwarzschild metric). Generalisation to the Kerr (rotation) and Reissner–Nordström (charge) metrics is necessary and may lead to new predictions related to the ergosphere and superradiance.

7. *Connection to quantum gravity.* ODTOE is not a theory of quantum gravity in the narrow sense: it does not quantise the metric tensor and does not introduce the graviton. However, the reinterpretation of the horizon as the boundary of $I(C)$ and the singularity as a region of $S = 0$ may be compatible with loop quantum gravity approaches (where the singularity is also resolved) and with the holographic principle (which is reinterpreted as a property of the mapping $\mathcal{H} \to \mathcal{C}$). Establishing formal connections with these approaches is a task for future work.

IX. CONCLUSION

A black hole in ODTOE is not a monster devouring reality. It is the ultimate mechanism of deconfiguration, returning actualised configurations to the space of potential states $\mathcal{H}$. The event horizon is an inertia boundary, not a physical barrier. The singularity is a region of zero coherence where no description holds any privilege. Information is not destroyed — it returns to where it was taken from.

Tidal disruption of a star is a cascading deconfiguration in which a highly coherent system is sequentially "disassembled" into elementary constituents. The flare energy is a measure of the lost coherence. Hawking radiation is spontaneous re-actualisation near the horizon, carrying correlations from $\mathcal{H}$.

The information paradox is resolved through an ontological shift: information lives not in the configuration space $\mathcal{C}$ but in the space of potentiality $\mathcal{H}$. Deconfiguration is injective and does not destroy distinctions. The firewall paradox is removed because the horizon is a boundary of observability, not a physical surface. The Page curve is reproduced through the non-separability of $\mathcal{H}$. The Penrose cosmic censorship hypothesis receives a natural justification: a region $S = 0$ cannot be accessible to an observer without an intermediate boundary $I(C) \to \infty$.

Quasi-periodic eruptions (QPE) are interpreted as repeated partial deconfiguration, and gravitational waves from black hole mergers as the release of configurational energy upon composition of $\hat{D}$ operators. Dark energy receives a conceptual (though speculative) interpretation as the pressure of the space of potentiality on configuration space.

The Universe breathes: the Big Bang is an inhalation ($\mathcal{H} \to \mathcal{C}$), black holes are an exhalation ($\mathcal{C} \to \mathcal{H}$). Neither process destroys information — both merely move configurations between the two spaces of a single reality.

Among open questions: formalisation of the operator $\hat{D}$ for rotating and charged black holes, derivation of exact quantitative predictions from first principles, establishment of connections with loop quantum gravity and island formulae, and development of experimental tests based on data from EHT, LIGO/Virgo/KAGRA and future X-ray observatories. Black holes are not the end of physics but a window into the fundamental structure of reality, where the boundary between the actual and the potential becomes observable.

The dawning era of multi-messenger astronomy — electromagnetic observations (EHT, eROSITA, ATHENA), gravitational-wave detectors (LIGO/Virgo/KAGRA, LISA, Einstein Telescope) and neutrino observatories — for the first time provides instruments for testing the predictions formulated in the present work. A black hole in ODTOE is not a mathematical abstraction but a physical process with observable consequences.

CONFLICT OF INTEREST

The author declares no conflict of interest.

FUNDING

This work was carried out without external funding.

REFERENCES

[1] Pankratov A. S. Theory of Everything: Observer-Dependent (Observer-Dependent Theory of Everything) // Preprint. — 2025. — 47 p.

[2] Hawking S. W. Particle creation by black holes // Communications in Mathematical Physics. — 1975. — Vol. 43. — P. 199–220. — DOI: 10.1007/BF02345020.

[3] Misner C. W., Thorne K. S., Wheeler J. A. Gravitation. — San Francisco: W. H. Freeman, 1973. — 1279 p.

[4] Event Horizon Telescope Collaboration. First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole // The Astrophysical Journal Letters. — 2019. — Vol. 875. — Art. L1. — DOI: 10.3847/2041-8213/ab0ec7.

[5] Abbott B. P. et al. (LIGO/Virgo Collaboration). Observation of Gravitational Waves from a Binary Black Hole Merger // Physical Review Letters. — 2016. — Vol. 116. — Art. 061102. — DOI: 10.1103/PhysRevLett.116.061102.

[6] Preskill J. Do Black Holes Destroy Information? // Proceedings of the International Symposium on Black Holes, Membranes, Wormholes and Superstrings. — Singapore: World Scientific, 1993. — P. 22–39.

[7] Almheiri A., Marolf D., Polchinski J., Sully J. Black Holes: Complementarity vs. Firewalls // Journal of High Energy Physics. — 2013. — Vol. 2013. — Art. 62. — DOI: 10.1007/JHEP02(2013)062.

[8] Rees M. J. Tidal disruption of stars by black holes of 10^6–10^8 solar masses in nearby galaxies // Nature. — 1988. — Vol. 333. — P. 523–528. — DOI: 10.1038/333523a0.

[9] Gezari S. Tidal Disruption Events // Annual Review of Astronomy and Astrophysics. — 2021. — Vol. 59. — P. 21–58. — DOI: 10.1146/annurev-astro-111720-030029.

[10] Hubble Observes New Tidal Disruption Event AT2024tvd // ESA/Hubble. — 2025. — URL: `https://esahubble.org/images/opo2515/`

[11] ScienceDaily. Rogue black hole shocks astronomers with record radio blast. — 2025. — URL: `https://www.sciencedaily.com/releases/2025/10/251016223026.htm`

[12] Pankratov A. S. The Cinematograph of Reality: Information, Memory and Reproduction in ODTOE // Preprint. — 2025.

[13] Pankratov A. S. The Atom as an Elementary Strange Loop in the Observer-Dependent Theory of Everything // Preprint. — 2025.

[14] Pankratov A. S. The Nature of Light and the Speed Limit: Reconfiguration Without Displacement in ODTOE // Preprint. — 2025.

[15] Pankratov A. S. Quantum, String and All the Rest: Modern Theories as Configurations Within ODTOE // Preprint. — 2025.

[16] Kormendy J., Ho L. C. Coevolution (Or Not) of Supermassive Black Holes and Host Galaxies // Annual Review of Astronomy and Astrophysics. — 2013. — Vol. 51. — P. 511–653. — DOI: 10.1146/annurev-astro-082708-101811.

[17] Barcelo C., Liberati S., Visser M. Analogue Gravity // Living Reviews in Relativity. — 2011. — Vol. 14. — Art. 3. — DOI: 10.12942/lrr-2011-3.

[18] Penrose R. Gravitational collapse: the role of general relativity // Rivista del Nuovo Cimento. — 1969. — Vol. 1. — P. 252–276.

[19] Miniutti G. et al. Nine-hour X-ray quasi-periodic eruptions from a low-mass black hole galactic nucleus // Nature. — 2019. — Vol. 573. — P. 381–384. — DOI: 10.1038/s41586-019-1556-x.

[20] Susskind L., Thorlacius L., Uglum J. The Stretched Horizon and Black Hole Complementarity // Physical Review D. — 1993. — Vol. 48. — P. 3743–3761. — DOI: 10.1103/PhysRevD.48.3743.

[21] ’t Hooft G. Dimensional Reduction in Quantum Gravity // Salamfestschrift: a collection of talks / Eds. A. Ali et al. — Singapore: World Scientific, 1993. — P. 284–296. — arXiv: gr-qc/9310026.

[22] Maldacena J. M. The Large N Limit of Superconformal Field Theories and Supergravity // Advances in Theoretical and Mathematical Physics. — 1998. — Vol. 2. — P. 231–252. — DOI: 10.4310/ATMP.1998.v2.n2.a1.

[23] Page D. N. Information in Black Hole Radiation // Physical Review Letters. — 1993. — Vol. 71. — P. 3743–3746. — DOI: 10.1103/PhysRevLett.71.3743.

[24] Maldacena J., Susskind L. Cool horizons for entangled black holes // Fortschritte der Physik. — 2013. — Vol. 61. — P. 781–811. — DOI: 10.1002/prop.201300020.

[25] Riess A. G. et al. Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant // The Astronomical Journal. — 1998. — Vol. 116. — P. 1009–1038. — DOI: 10.1086/300499.

[26] Punturo M. et al. The Einstein Telescope: a third-generation gravitational wave observatory // Classical and Quantum Gravity. — 2010. — Vol. 27. — Art. 194002. — DOI: 10.1088/0264-9381/27/19/194002.