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The Macro Transcension Hypothesis: Spinning Black Holes in Dense Stellar Clusters as Thermodynamic Attractors for Advanced Civilizations, with Omega Centauri as an Observational Test Bed

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⬇ PDF

⇔ Observational companion paper (campaign)

⇔ Review of the inward-migration family

References

Falsification table

⚠ **EPISTEMIC STATUS.** This paper mixes established physics (Sections 4–5, clearly cited) with an explicitly speculative hypothesis (Sections 3, 6). The gas-starvation null hypothesis is adopted as the default explanation for all current observations throughout. Nothing here claims a detection of extraterrestrial intelligence.

ABSTRACT

Most proposed resolutions of the Fermi paradox assume that long-lived technological civilizations either expand outward, perish, or deliberately hide. We develop a fourth alternative, the *Macro Transcension Hypothesis* (MTH): that civilizations which optimize for long-term computation are driven by thermodynamics — not choice — toward a specific class of astrophysical environment, namely rapidly spinning massive black holes embedded in dense, old stellar systems, and that the migration and its endpoint are both electromagnetically quiet. The MTH extends the transcension hypothesis of Smart (2012) from planet-scale "inner space" to macroscopic black-hole infrastructure, and differs from the aestivation hypothesis of Sandberg, Armstrong & Ćirković (2016) in requiring no waiting strategy: the relevant free-energy and entropy-disposal advantages are available now. We quantify the case in four steps: (i) thin-disk accretion onto a Kerr black hole releases 5.7–42 per cent of rest-mass energy, versus 0.7 per cent for hydrogen fusion, while magnetically arrested disks extract additional spin energy at effective efficiencies exceeding 100 per cent of accreted rest mass; (ii) by the generalized second law, an event horizon is a thermodynamically ideal entropy sink, permitting computation arbitrarily close to the Landauer bound with negligible radiated waste heat; (iii) the Bekenstein–Hawking entropy of a $\sim 2\times 10^{4}\ M_\odot$ black hole corresponds to $\sim 10^{86}$ bits, exceeding any material archive; and (iv) per unit of harvested mass, this architecture outperforms Dyson-type stellar harvesting by a factor of ~40–60 in lifetime energy yield and by $\sim 10^{9}$ in instantaneous Eddington-limited power for a $2\times 10^{4}\ M_\odot$ hole. We then identify Omega Centauri (NGC 5139) — a $\sim 4\times 10^{6}\ M_\odot$, ~12-Gyr-old stripped dwarf-galaxy nucleus hosting the nearest strong candidate intermediate-mass black hole — as the most observationally accessible system satisfying the MTH selection criteria, and present a falsification framework built on six instrument-matched tests: accretion-luminosity limits (JWST, ATCA), mid-infrared waste-heat limits, LISA extreme-mass-ratio-inspiral mass and spin measurements, millisecond-pulsar timing, stellar proper-motion accelerations, and neutrino burst searches (KM3NeT). Current data — including the unresolved tension between a $\geq 8{,}200\ M_\odot$ kinematic lower bound (Häberle et al. 2024) and a $\lesssim 6{,}000\ M_\odot$ pulsar-timing upper bound (Bañares-Hernández et al. 2025), and the complete electromagnetic silence of the central object (Mahida et al. 2026; Chen et al. 2025) — are consistent with both the MTH and the more parsimonious gas-starvation null hypothesis; we state explicitly which forthcoming observations would discriminate between them, and which would falsify the MTH outright. The hypothesis is offered in the falsificationist tradition of the aestivation and black-hole-computing literature: a speculative but physically grounded working model whose value lies in the concrete observational program it motivates.

Keywords: Fermi paradox · technosignatures · SETI · intermediate-mass black holes · Omega Centauri · NGC 5139 · Blandford–Znajek mechanism · Landauer limit · transcension · aestivation

Contents

1. Introduction

The Fermi paradox, in its modern form (Hart 1975; Tipler 1980; Webb 2015; Ćirković 2018; Forgan 2019), rests on an expansionist premise: that at least some technological civilizations should grow outward across interstellar distances, and that such growth, sustained for even a small fraction of galactic history, would be conspicuous. The premise is quantitatively robust. Self-reproducing probe architectures permit galaxy-scale colonization in 10^6–10^8 years (Tipler 1980; Freitas & Gilbreath 1982), intergalactic expansion is energetically cheap for a mature civilization (Armstrong & Sandberg 2013), and surveys for the waste heat of large-scale energy harvesting have returned null results across ~10^5 galaxies (Wright et al. 2014; Griffith et al. 2015). The observed silence therefore demands either that technological life is extremely rare, that it reliably destroys itself, or that the expansionist premise is wrong.

A minority tradition in the literature attacks the premise itself. Smart (2012) proposed the *transcension hypothesis*: that the developmental trajectory of intelligence points not outward but inward, toward ever denser, faster, and more efficient configurations of matter and energy — "STEM compression" of space, time, energy, and matter — terminating, in Smart's telling, at black-hole-scale densities and an effective exit from the observable universe. Sandberg, Armstrong & Ćirković (2016) proposed the *aestivation hypothesis*: that civilizations which value computation should defer it to the far future, when the cosmic microwave background (CMB) has cooled and each erased bit costs less free energy, and should therefore be dormant now. Both proposals share a key insight — that the thermodynamics of computation, not the romance of exploration, is the correct lens through which to predict the behaviour of mature intelligence — and both have been criticized on physical grounds. Smart's mechanism for leaving the universe is not specified in testable form, and the aestivation argument was shown by Bennett, Hanson & Riedel (2019) to rest on a thermodynamic error: free energy not harvested now is largely lost, not banked, so a computation-maximizing civilization should collect resources *now* even if it spends them later.

This paper develops a third member of that family, which we call the *Macro Transcension Hypothesis* (MTH). Its core claim is that the inward trajectory identified by Smart has a concrete, macroscopic, observationally accessible destination in ordinary astrophysics: rapidly spinning massive black holes embedded in dense, dynamically old stellar systems. No new physics, no exit from the universe, and no multi-gigayear dormancy are required. The advantages that drive the migration — accretion power at up to ~60 times the mass-energy efficiency of fusion, an event horizon serving as an entropy sink of unlimited capacity, information storage at the Bekenstein–Hawking density, and gravitational time dilation as a controllable computational resource — are all available in the present epoch, and all follow from textbook general relativity and black-hole thermodynamics (Misner, Thorne & Wheeler 1973; Bardeen, Press & Teukolsky 1972; Bekenstein 1973, 1974). The hypothesis predicts that the most advanced civilizations are not absent but *electromagnetically invisible*, because maximum computational efficiency, viewed from outside, looks like silence.

The MTH would remain idle philosophy if it did not select targets. It does. The selection criteria — a massive black hole of modest depth (intermediate, not supermassive), a dense retinue of low-mass stars as fuel, dynamical age sufficient for any migrating civilization to have arrived and matured, and a quiescent electromagnetic environment — converge on a short list of Galactic systems, at the top of which sits Omega Centauri (ω Cen, NGC 5139): the Milky Way's most massive globular cluster, widely interpreted as the stripped nucleus of an accreted dwarf galaxy (Hilker & Richtler 2000; Bekki & Tsujimoto 2019; Ibata et al. 2019), host to ~10^7 stars of mean age 12.08 ± 0.01 Gyr (Clontz et al. 2024), and — since the detection of seven fast-moving stars within its central 3 arcsec — host to the strongest current candidate for an intermediate-mass black hole (IMBH) in the Galaxy (Häberle et al. 2024a). That candidate is simultaneously the subject of a sharp observational controversy: combined stellar-kinematic and millisecond-pulsar-timing analysis places a 3σ *upper* limit of ~6,000 $M_\odot$ on any central point mass (Bañares-Hernández et al. 2025), formally inconsistent with the kinematic lower bound. And it is electromagnetically dark to remarkable depth: neither ~170 hours of ATCA radio integration (Mahida et al. 2026) nor JWST infrared photometry (Chen et al. 2025) detects any accretion signature. Every element of this situation — a contested central mass, perfect electromagnetic silence, an imminent decisive instrument (LISA) — makes ω Cen a natural laboratory for testing inward-migration hypotheses, entirely independent of whether the MTH is true.

1.1 Claims and non-claims

We are explicit about epistemic register, since the argument mixes established physics with speculative inference. The paper makes three claims of different strength:

1. **(Established physics.)** Spinning black holes in dense old clusters are, by a wide quantitative margin, the most thermodynamically favourable environments in the present-day universe for long-term, large-scale computation. This claim is defended in Section 4 using standard results and is independent of any claim about extraterrestrial intelligence.
2. **(Speculative hypothesis.)** If long-lived technological civilizations exist and even a subset optimizes for computational capacity, the environments of claim 1 act as attractors, and the resulting migration resolves the Fermi paradox without rare-Earth or doomsday assumptions. This is the MTH proper, stated formally in Section 3. We regard it as less parsimonious than the null hypothesis (technological life is rare or absent) and say so.
3. **(Observational program.)** Whether or not claim 2 is true, it generates instrument-matched, time-bounded, falsifiable predictions at ω Cen, several of which will be adjudicated by existing or funded instruments within ~15 years. This program is presented in Section 7.

We do *not* claim that ω Cen hosts a civilization; we do not claim the IMBH is confirmed (it is not); and we do not claim the observed electromagnetic silence is evidence for the MTH, since it is equally consistent with the simpler gas-starvation explanation that we adopt as the null hypothesis throughout.

2. Relation to prior work

2.1 The expansionist mainstream

The canonical statements of the Fermi paradox (Hart 1975; Tipler 1980) treat interstellar expansion as the default behaviour of technological life, an assumption sharpened by Armstrong & Sandberg (2013), who showed that a single mature civilization could seed every galaxy within several billion light-years using a fraction of one star's output. The "grabby aliens" model of Hanson et al. (2021) quantifies the selection effect: if loud (expanding) civilizations exist at any appreciable rate, they dominate the future light cone, and our own early arrival is informative about their density. Observational programs built on the expansionist premise — radio and optical SETI (Tarter 2001), waste-heat surveys (Dyson 1960; Wright et al. 2014; Griffith et al. 2015), and the broader technosignature framework (Wright et al. 2022; Socas-Navarro et al. 2021; Lingam & Loeb 2021) — have produced consistent null results. Within the expansionist frame, these nulls force the unattractive trilemma of rarity, doom, or concealment.

2.2 The inward-migration family

The MTH belongs to a smaller family of proposals holding that mature intelligence migrates down thermodynamic gradients rather than out across space.

Transcension. Smart (2012) argued that the developmental history of complexity on Earth exhibits sustained compression in space, time, energy, and matter ("STEM compression"), and extrapolated to a future in which civilizations engineer environments of black-hole density and disappear from the observable universe. The MTH adopts the compression premise but rejects the terminal step: nothing in known physics permits or requires an exit from the universe, and a hypothesis terminating in unobservable territory cannot be tested. The MTH instead halts the inward trajectory at a *macroscopic* astrophysical object — an existing massive black hole — where every claimed advantage is calculable and several are observable. Hence *macro* transcension.

Aestivation. Sandberg, Armstrong & Ćirković (2016) proposed that civilizations defer computation until the CMB cools, gaining a factor of up to ~10^{30} in computations per joule, and so should currently be dormant. Bennett, Hanson & Riedel (2019) showed the argument neglects the irreversible loss of free-energy resources not collected promptly: stars burn whether or not anyone harvests them, so maximizers should be active *now*. The MTH is immune to this objection by construction. Its central thermodynamic move is not waiting for a colder universe but *importing a colder-than-CMB entropy sink into the present*: waste entropy crossing an event horizon increases horizon area in accordance with the generalized second law (Bekenstein 1974), at an effective marginal temperature far below the CMB's 2.7 K (Section 4.2). An MTH civilization harvests aggressively in the present epoch — consistent with the Bennett–Hanson–Riedel optimality argument — while enjoying most of the efficiency gain that motivated aestivation.

Black holes as civilization infrastructure. Several authors have treated black holes as energy sources or computational substrates for advanced intelligence: Inoue & Yokoo (2011) proposed Dyson-type collectors around an accreting supermassive black hole; Hsiao et al. (2021) computed the detectability of a "Dyson sphere around a black hole" harvesting disk luminosity; Vidal (2011, 2014) argued that black-hole-coupled ("stellivore") systems are the natural attractor for cosmic intelligence; and Dvali & Osmanov (2023) analysed black holes as quantum information processors for extraterrestrial civilizations, predicting characteristic high-energy neutrino emission from artificial micro-black-hole computers. Lacki & DiKerby (2025) survey the corresponding high-energy SETI opportunity. The MTH synthesizes this thread and adds the two elements it has lacked: a *selection theory* specifying which black holes are preferred and why (intermediate-mass, high-spin, cluster-embedded; Section 3.1), and a *named, ranked observational target* with a costed test program.

Kardashev and his inversion. The Kardashev scale (Kardashev 1964) ranks civilizations by total energy throughput, implicitly rewarding outward expansion. Barrow (1998) proposed the complementary inward scale: mastery over ever-smaller scales of structure. The MTH is the astrophysical completion of Barrow's inversion — the observation that the universe already provides, free of charge, the densest stable structures that inward mastery could aim at, and that the rational endpoint of a Barrow-type trajectory is therefore relocation rather than fabrication. Bradbury (1999) reached a related conclusion from the engineering side: his Matrioshka-brain analysis shows stellar-powered computation is ultimately limited by radiator area and sink temperature — precisely the constraints an event horizon eliminates.

2.3 What is new here

To our knowledge this paper is the first to (i) state the inward-migration resolution of the Fermi paradox as a falsifiable selection theory over real astrophysical objects; (ii) integrate the generalized second law, the Landauer bound, Kerr accretion efficiency, Blandford–Znajek extraction, and Bekenstein–Hawking storage into a single quantitative budget for a civilization-scale computer hosted by an existing black hole; and (iii) attach the resulting predictions to a specific system (ω Cen) with instrument-matched falsification thresholds and timelines. Each ingredient exists in the literature; the synthesis, the selection criteria, and the test program are new.

3. The hypothesis

EPISTEMIC STATUS: Sections 3–4 contain, respectively, a speculative hypothesis stated formally, and established physics offered in its support. The physics in Section 4 stands regardless of the hypothesis.

We state the MTH as four postulates.

> **P1 (Optimization pressure).** Among long-lived technological civilizations, a non-empty subset evolves — by competition, self-modification, or design — toward maximizing long-term computational capacity per unit of controlled resource. *(Motivation: computation is the universal currency into which information-processing agents can convert essentially any terminal goal; this is the same premise adopted by Smart 2012 and Sandberg et al. 2016.)*

> **P2 (Thermodynamic gradient).** For any such maximizer, the present-day universe contains a strict gradient of substrate quality whose global optima are rapidly spinning massive black holes embedded in dense, old, low-luminosity stellar systems. The gradient is set by four independent physical quantities: extractable energy per unit fuel mass, entropy-disposal capacity, information-storage density, and control over effective clock rate. *(Defended quantitatively in Section 4.)*

> **P3 (Quiet migration).** Migration toward and exploitation of such environments is electromagnetically inconspicuous at interstellar distances. Transit uses gram-to-kilogram-scale beamed-sail payloads rather than worldships (Lubin 2016); construction uses in-situ resources (Freitas & Gilbreath 1982); and mature operation, by the very efficiency that motivates it (P2), radiates negligible waste heat (Section 4.2).

> **P4 (Observable residue).** The endpoint is nevertheless not perfectly unobservable. It predicts (a) anomalously high spin on the host black hole; (b) suppressed or absent accretion luminosity relative to ambient gas supply; (c) depletion of the loosely bound stellar population over Gyr timescales; and (d) possibly, burst-mode high-energy neutrino emission if micro-

> black-hole computation of the Dvali–Osmanov type is employed. These residues define the falsification program of Section 7.

The hypothesis (MTH). *If P1–P3 hold, then the oldest computation-maximizing civilizations in the Galaxy have already relocated to environments of the P2 class; their absence from planetary systems, the radio spectrum, and waste-heat surveys is a selection effect of the thermodynamic gradient; and the appropriate search strategy is targeted scrutiny of the small set of P2-optimal Galactic systems for the P4 residues.*

Three corollaries sharpen the contrast with neighbouring hypotheses. First, against aestivation: the MTH predicts *present activity* in P2 environments, not dormancy, so it is not vulnerable to the Bennett–Hanson–Riedel objection. Second, against the dark-forest family of concealment hypotheses: silence here is a by-product of efficiency, not a strategic choice, so the MTH requires no game-theoretic coordination among civilizations. Third, against Smart's original transcension: every MTH process occurs in ordinary spacetime around an ordinary Kerr black hole, so the hypothesis remains permanently coupled to observation.

3.1 Selection criteria over host systems

P2 implies a ranking of real systems. The optimum is set by competing requirements:

1. **Black-hole mass in the intermediate range (10^3–10^5 $M_\odot$).** Energy extraction scales with available fuel and with Eddington-limited throughput ($\propto M$), favouring larger M; but tidal disruption of solid infrastructure at the innermost stable circular orbit (ISCO) becomes *less* constraining at larger M, while two costs grow with M: the Bekenstein–Hawking storage already saturates any plausible need at 10^4 $M_\odot$, and supermassive holes sit in deep galactic-centre potentials crowded with disruptive astrophysics (Section 5.4). The intermediate range secures every advantage at minimal exposure.
2. **High spin, or spin-up feasibility.** The Blandford–Znajek channel and the deep-ISCO efficiencies require $a_\star \gtrsim 0.9$; a hole of modest spin can be spun up by prograde disk accretion at a calculable mass cost (Thorne 1974), provided fuel exists (criterion 3).
3. **A dense, old, low-mass stellar reservoir.** Sustained Eddington-limited feeding of a $\sim 2\times10^4$ $M_\odot$ hole consumes of order one solar mass per two millennia; a globular-cluster core supplies 10^5–

10^6 low-mass stars within a parsec at relative velocities of tens of km s^{-1} — fuel that is, crucially, *useless to fusion-era civilizations* and therefore uncontested.

4. **Dynamical age and quiescence.** A system $\gtrsim$10 Gyr old has been reachable by any Galactic civilization arising in the first stellar generations; a relaxed, gas-poor environment minimizes both natural accretion noise and hazards to infrastructure.

Milky Way globular clusters with massive-IMBH candidates satisfy all four criteria simultaneously; ω Cen satisfies them maximally (Section 5). The Galactic Centre fails criteria 1 and 4; isolated stellar-mass black holes fail criterion 3; young massive clusters fail criterion 4.

4. The thermodynamic and computational case

This section defends postulate P2 quantitatively. Throughout, M is the black-hole mass, $a_\star \equiv Jc/GM^2 \in [0,1)$ the dimensionless spin, $r_g \equiv GM/c^2$ the gravitational radius, and we evaluate fiducial numbers at $M = 2\times10^4\ M_\odot$, the geometric midpoint of the contested ω Cen range (Section 5). All results in this section are standard physics; no claim about extraterrestrial intelligence is made until Section 6.

4.1 Energy: accretion and spin extraction versus fusion

Thin-disk efficiency. Matter spiralling through a geometrically thin, radiatively efficient disk is released at the ISCO binding energy. For a circular equatorial orbit around a Kerr hole, the specific energy at the ISCO gives a radiative efficiency (Bardeen, Press & Teukolsky 1972; Novikov & Thorne 1973)

$$\eta(a_\star) = 1 - E_{ISCO} = 1 - \sqrt{(1 - \tfrac{2}{3} \cdot r_g/r_{ISCO}(a_\star))} \qquad (1)$$

which rises from $\eta = 1 - \sqrt{(8/9)} \approx 0.057$ at $a_\star = 0$ ($r_{ISCO} = 6\ r_g$) to 0.321 at the Thorne (1974) radiative spin-equilibrium limit $a_\star = 0.998$, and formally to $1 - 1/\sqrt{3} \approx 0.423$ as $a_\star \to 1$ (Fig. 1). Hydrogen fusion releases 0.71 per cent of rest mass, of which a main-sequence star processes roughly a tenth over its lifetime; a Dyson-type collector (Dyson 1960) therefore captures a *lifetime* yield of order 7×10^{-4} of stellar mass. Per unit of fuel mass under the civilization's control, disk accretion onto a high-spin hole thus outperforms complete fusion of the same mass by a factor of ~8 (Schwarzschild) to ~60 (extremal), and outperforms realistic Dyson harvesting of the same stellar mass by a factor of ~80–600.

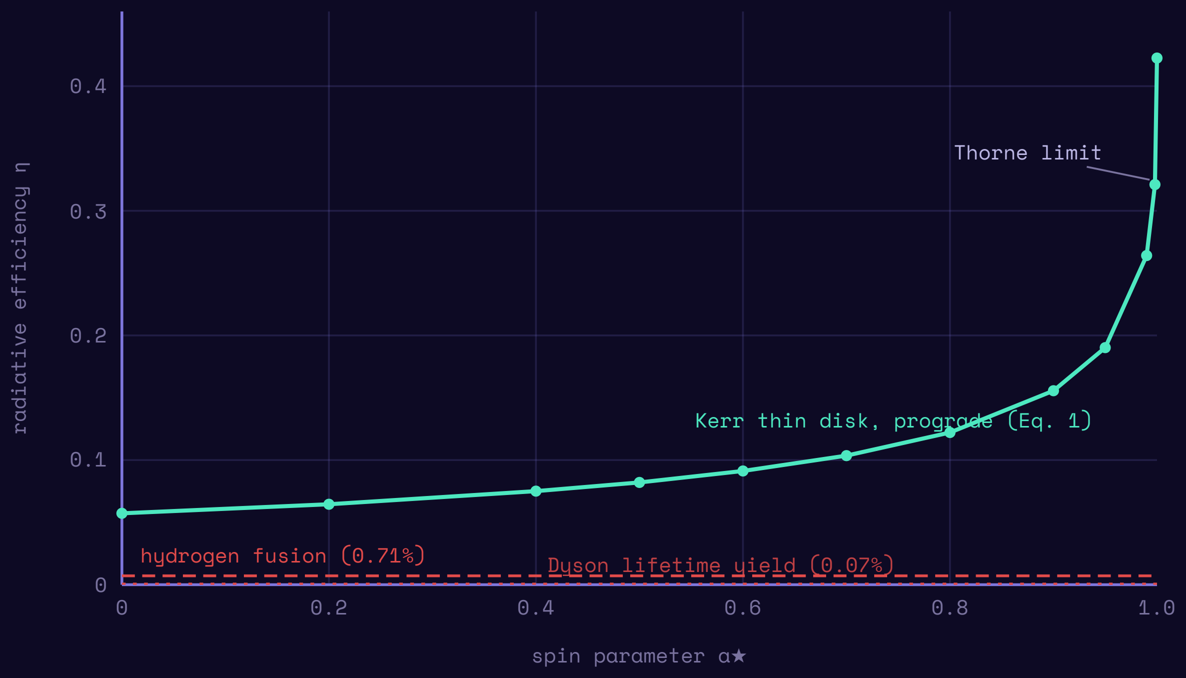

Figure 1. Mass-to-energy conversion efficiency of thin-disk accretion as a function of black-hole spin (Bardeen, Press & Teukolsky 1972; Novikov & Thorne 1973), compared with hydrogen fusion and with the lifetime yield of Dyson-type stellar harvesting. The Thorne (1974) limit $a_\star = 0.998$ ($\eta \approx 0.32$) marks the equilibrium spin reachable by disk accretion alone. Curve drawn through exact values of Eq. (1) at the plotted points.

Power throughput. The sustainable luminosity is bounded by the Eddington limit,

$$L_{Edd} = 4\pi G M m_p c/\sigma_T \approx 1.26\times10^{31}\ (M/M_\odot)\ \mathrm{W} \tag{2}$$

giving 1.0×10^{35}, 2.5×10^{35}, and 6.3×10^{35} W at $M = 8.2\times10^3$, 2×10^4, and $5\times10^4\ M_\odot$ respectively (Frank, King & Raine 2002; Shapiro & Teukolsky 1983) — some ~10^9 times the bolometric output of the Sun, and hence of any solar Dyson swarm (Fig. 2). The corresponding Eddington accretion rate, $\dot{M}_{Edd} = L_{Edd}/\eta c^2$, is remarkably modest: at $\eta = 0.1$ and $M = 2\times10^4\ M_\odot$, one solar mass sustains the limit for ~2,300 years. A globular-cluster core containing $\gtrsim10^5$ stars within its central parsec can therefore fuel Eddington-limited operation for ~10^{8-9} years using bodies (brown dwarfs, low-mass M dwarfs, white dwarfs) that no fusion-based economy values.

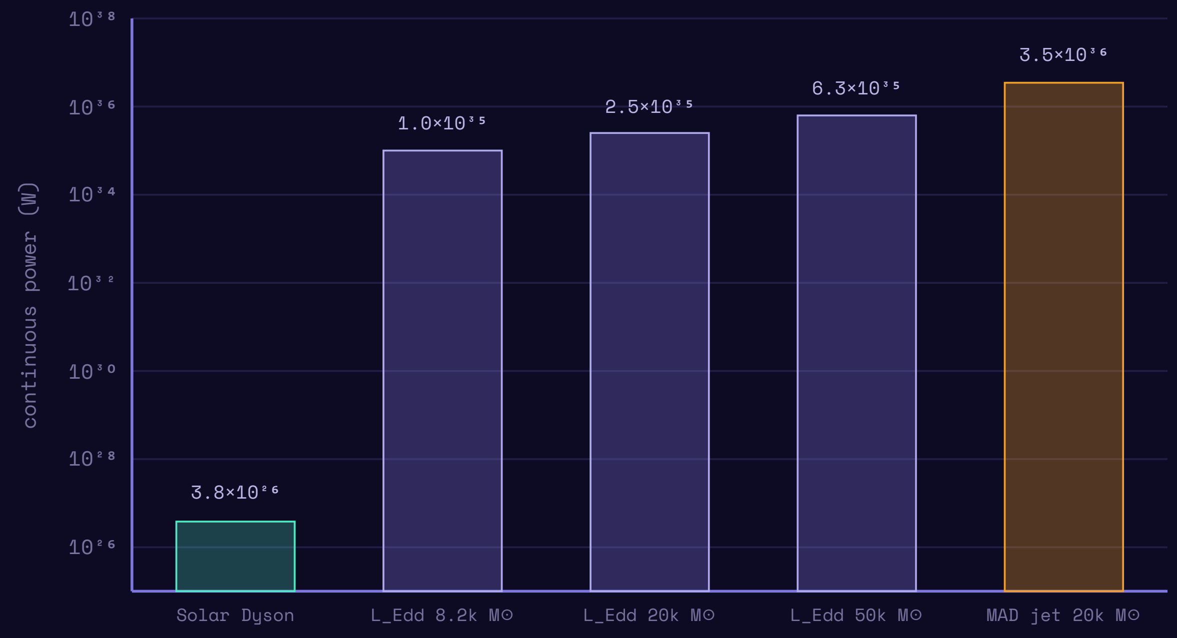

Figure 2. Continuous power available from a complete solar Dyson swarm versus Eddington-limited accretion (Eq. 2) onto IMBHs spanning the contested ω Cen mass range, and a magnetically arrested (MAD) Blandford–Znajek jet at $a_\star \approx 0.99$ with $\eta_{\mathrm{jet}} \approx 1.4$ (Tchekhovskoy, Narayan & McKinney 2011), fed at the $\eta = 0.1$ Eddington rate. The IMBH advantage in instantaneous power is roughly nine orders of magnitude.

Spin energy and the Blandford–Znajek channel. A Kerr hole stores extractable rotational energy

$$E_{\mathrm{rot}} = [1 - \sqrt{(\tfrac{1}{2}(1 + \sqrt{(1 - a_\star{}^2)}))}]\, Mc^2 \tag{3}$$

reaching $0.29\, Mc^2 \approx 1.0\times10^{51}$ J for $M = 2\times10^4\, M_\odot$ as $a_\star \to 1$ — a reservoir equal to the entire lifetime fusion output of ~10^7 Suns, storable indefinitely and tappable on demand. That this energy is extractable in principle was shown by the ergosphere mechanism of Penrose (1969) and Penrose & Floyd (1971); the astrophysically efficient extraction mechanism is electromagnetic: a horizon threaded by poloidal magnetic flux Φ supplied by an accretion disk acts as a unipolar inductor, driving Poynting-flux jets with power $P_{\mathrm{BZ}} \propto \Phi^2\Omega_H{}^2$, where Ω_H is the horizon angular frequency (Blandford & Znajek 1977). In the magnetically arrested disk (MAD) regime, general-relativistic magnetohydrodynamic simulations find jet efficiencies $\eta_{\mathrm{jet}} \equiv P_{\mathrm{jet}}/\dot{M}c^2 \approx 1.4$ at $a_\star \approx 0.99$ (Tchekhovskoy, Narayan & McKinney 2011; Tchekhovskoy 2015) — the jet carries *more* energy than the accreted rest mass, the excess drawn from spin. The BZ scaling has recently been confirmed from first principles by ab-initio particle-in-cell simulations of Kerr magnetospheres (Meringolo, Camilloni & Rezzolla 2025), which additionally identify equatorial magnetic reconnection as a supplementary extraction channel (Comisso & Asenjo 2021; Camilloni & Rezzolla 2025); one 2026 preprint reports transient MAD states with jet power exceeding accretion power by over two orders of magnitude (Nathanail 2026, not yet peer-reviewed). For the MTH it suffices that $\eta_{\mathrm{jet}} \gtrsim 1$ is robust across methods: an engineered MAD configuration around a spun-up IMBH is, per unit fuel, the most efficient large-scale power plant permitted by demonstrated physics.

Spin-up economics. A hole of low natal spin is itself improvable. Prograde thin-disk accretion drives $a_\star \to 0.998$ after the hole grows by a factor ≈2.4 (Thorne 1974); for an initial $2\times10^4\ M_\odot$ hole this costs $\sim3\times10^4\ M_\odot$ of accreted matter — of order 10^{4-5} cluster stars — and, at Eddington throughput, $\sim10^8$ years. The investment multiplies all subsequent per-unit-fuel returns by up to ~6 (Fig. 1) and unlocks the BZ reservoir. We emphasize the corollary for observers: *spin is the single most diagnostic parameter of the system's history* (Section 7), since natural IMBH formation channels do not generically predict near-extremal spin, whereas the MTH requires engineered systems to approach it.

4.2 Entropy disposal: the horizon as the ultimate cold reservoir

Landauer's principle sets the minimum thermodynamic cost of irreversible computation: erasing one bit dissipates at least $k_B T \ln 2$ into a reservoir at temperature T (Landauer 1961; Bennett 1982; Parrondo, Horowitz & Sagawa 2015), a bound verified experimentally (Bérut et al. 2012). Reversible logic evades the bound for intermediate steps (Bennett 1973; Toffoli 1980; Fredkin & Toffoli 1982; Athas et al. 1994; Frank 2002), but error correction, measurement, and memory reuse impose a residual erasure budget on any real computer (Wolpert 2019). For a conventional deep-space computer the reservoir floor is the CMB at $T_\gamma = 2.7$ K, so the marginal cost is $k_B T_\gamma \ln 2 = 2.6\times10^{-23}$ J per bit. This is the floor that aestivation proposes to lower by waiting $\sim10^{12}$ years (Sandberg et al. 2016).

An event horizon lowers it *now*. By the generalized second law (GSL), the sum of black-hole entropy $S_{BH} = k_B c^3 A/4G\hbar$ and exterior entropy is non-decreasing, and entropy carried across the horizon is accounted by the area increase (Bekenstein 1973, 1974; Bousso 2002). A computation platform orbiting the hole may therefore dump its waste entropy into the horizon rather than radiating it to the sky. The marginal energy cost of horizon disposal is set by the horizon temperature

$$T_H = \hbar c^3/8\pi G M k_B \approx 6.2\times10^{-8}\ (M_\odot/M)\ \mathrm{K} \tag{4}$$

(Hawking 1974, 1975): $T_H \approx 3\times10^{-12}$ K at $2\times10^4\ M_\odot$ — *twelve orders of magnitude below the CMB*. A bit dumped at the horizon costs $k_B T_H \ln 2 \sim 3\times10^{-35}$ J against 2.6×10^{-23} J for CMB radiation (Fig. 3). In practical terms the erasure cost ceases to be the binding constraint on computation; the budget shifts to transport of waste heat to the horizon (radiative or conductive tethering from the ISCO swarm inward), an engineering loss rather than a thermodynamic floor. This single substitution captures essentially the entire $\sim10^{30}$ efficiency factor that motivated aestivation — without waiting, and therefore without forfeiting the free energy that Bennett, Hanson & Riedel (2019) showed dormant civilizations irretrievably lose.

Figure 3. Landauer cost per erased bit, $k_B T \ln 2$, as a function of reservoir temperature. Dumping waste entropy across an IMBH horizon (marginal temperature T_H, Eq. 4) rather than radiating to the CMB lowers the erasure floor by $\sim10^{12}$, in the present epoch, consistent with the generalized second law (Bekenstein 1974). This is the efficiency gain that the aestivation hypothesis (Sandberg et al. 2016) sought by waiting $\sim10^{12}$ years for cosmological cooling.

4.3 Information storage: the Bekenstein-Hawking archive

The Bekenstein bound limits the information content of any bounded system (Bekenstein 1981; Casini 2008); black holes saturate it, with

$$S_{BH}/k_B \ln 2 \approx 1.5\times10^{77}\,(M/M_\odot)^2 \text{ bits} \tag{5}$$

i.e. $\sim 6\times10^{85}$ bits at $2\times10^{4}\ M_\odot$ (Bekenstein 1973; Lloyd 2000). Information crossing the horizon is scrambled but, by unitarity, not destroyed; retrieval timescales via Hawking radiation are, however, of order the evaporation time, $\sim10^{67}(M/M_\odot)^3$ yr (Page 1976) — the archive is functionally write-only. Black holes likewise saturate the Margolus–Levitin bound on processing rate, $2E/\pi\hbar$ operations per second (Margolus & Levitin 1998; Lloyd 2000). We treat these saturation properties not as a usable disk drive but as the formal statement that no material technology can out-store or out-compute the object the civilization is already orbiting: the substrate ceiling and the chosen environment coincide.

4.4 Time dilation as an engineering parameter

A platform on a circular equatorial geodesic at radius r around a Kerr hole runs slow relative to infinity by

$$d\tau/dt = \sqrt{(1 - 3r_g/r + 2a_\star(r_g/r)^{3/2})} \;/\; (1 + a_\star(r_g/r)^{3/2}) \tag{6}$$

(Bardeen, Press & Teukolsky 1972): $d\tau/dt = \sqrt{\tfrac{1}{2}} \approx 0.707$ at the Schwarzschild ISCO, falling to ≈ 0.093 (a factor ~11) at the prograde ISCO for $a_\star = 0.998$ (Fig. 4). Larger factors require powered non-geodesic hovering at diverging thrust cost and are not usable by stable platforms; popular claims of 1000:1 dilation at stable orbits are incorrect by 1–2 orders of magnitude. A tiered swarm can therefore place archival and slow-integration processes deep (subjectively skipping across external time) and interactive processes high, with the choice of orbit acting as a clock-rate dial — a resource with no terrestrial analogue, though we note its strategic value (e.g. outwaiting external change) trades directly against responsiveness.

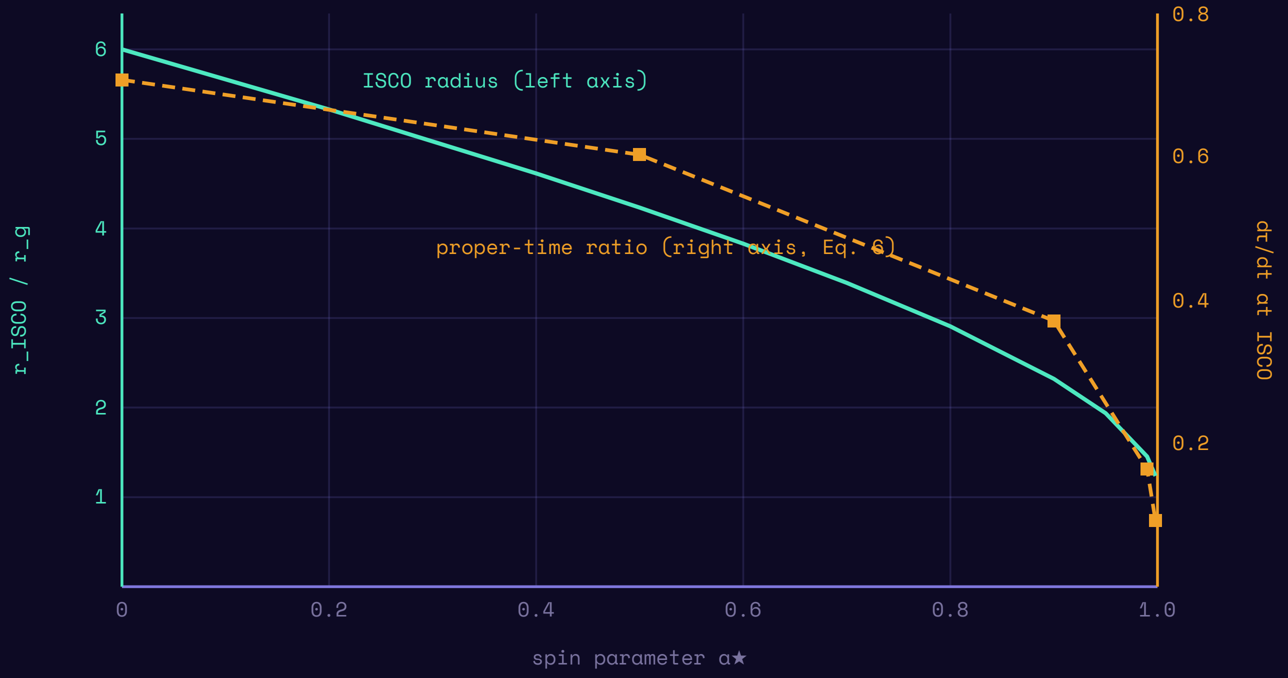

Figure 4. Prograde ISCO radius (left axis) and proper-time ratio for a circular geodesic at the ISCO (right axis) as functions of spin (Bardeen, Press & Teukolsky 1972). Spin-up from $a_\star = 0$ to the Thorne limit moves the working orbit from 6 r_g to 1.24 r_g and deepens the available stable time dilation from 1.41:1 to ~11:1.

4.5 Why inward beats outward for a computation-maximizer

The expansionist default implicitly maximizes *resource acquisition*; P1 civilizations maximize *computation*, and the two diverge. Expansion multiplies harvested mass at most polynomially in time ($\propto t^3$ for spherical growth at fixed speed) while imposing light-lag decoherence on any shared computation: a civilization spread over 10^3 light-years cannot function as one computer on subjective timescales shorter than millennia. Concentration, by contrast, multiplies the *yield per unit mass* by the factors of Section 4.1 (up to ~600 over Dyson harvesting), lowers the erasure floor by ~10^{12} (Section 4.2), and keeps the entire system within light-seconds of itself. For any utility function dominated by total integrated computation, the gradient points inward once beamed-sail transport makes a cluster-hosted IMBH reachable at negligible marginal cost (Lubin 2016; Armstrong & Sandberg 2013). We stress the modesty of the claim actually needed: P1 requires only that *some* civilizations follow this gradient. Expansionist and stay-at-home civilizations may coexist with migrators; the Fermi-relevant point is that the oldest and most capable optimizers — precisely those whose absence the paradox finds most puzzling (Hanson et al. 2021) — are the ones the gradient captures.

5. Omega Centauri as the optimal observational target

5.1 The cluster

ω Centauri is the most massive Galactic globular cluster ($M_{\mathrm{cl}} \approx 4{\times}10^{6}\ M_{\odot}$, ~$10^{7}$ stars; Baumgardt & Hilker 2018), at a kinematic distance of 5.49 ± 0.06 kpc (Häberle et al. 2025), consistent within systematics with the Gaia EDR3 parallax (5.24 ± 0.11 kpc; Soltis, Casertano & Riess 2021) and the combined catalogue value (5.43 ± 0.05 kpc; Baumgardt & Vasiliev 2021). It is anomalous among globular clusters in nearly every respect that matters here: it hosts multiple stellar populations spanning a broad metallicity range (Johnson & Pilachowski 2010), a mean stellar age of 12.08 ± 0.01 Gyr with an intrinsic spread of 0.75 Gyr (Clontz et al. 2024), significant rotation, and an associated tidal stream (Ibata et al. 2019) — the consensus interpretation being that it is the surviving nucleus of a dwarf galaxy accreted and stripped by the Milky Way (Hilker & Richtler 2000; Bekki & Tsujimoto 2019). Table 1 summarizes the parameters used in this paper.

For the MTH selection criteria of Section 3.1, the stripped-nucleus origin matters twice over. First, nuclear star clusters are the environments most likely to form and retain IMBHs (Greene, Strader & Ho 2020). Second, the age structure implies that any technological lineage arising anywhere in the progenitor dwarf — or in the early Milky Way — has had $\gtrsim 8$ Gyr to locate, reach, and develop the system: at beamed-sail transit speeds of 0.1–0.2 c (Lubin 2016), crossing the Galaxy takes $\lesssim 10^{6}$ years, five thousand times less than the available window.

Table 1. Adopted parameters for ω Centauri (NGC 5139).

QUANTITY	VALUE	SOURCE
Distance	5.49 ± 0.06 kpc	Häberle et al. (2025)
Cluster mass	$\approx 4{\times}10^{6}\ M_{\odot}$	Baumgardt & Hilker (2018)
Stellar count	~10^{7}	Baumgardt & Hilker (2018)

QUANTITY	VALUE	SOURCE
Mean stellar age	12.08 ± 0.01 Gyr (spread 0.75 Gyr)	Clontz et al. (2024)
Origin	stripped dwarf-galaxy nucleus	Hilker & Richtler (2000); Ibata et al. (2019)
Central density	$\sim 10^3\ M_\odot\ \mathrm{pc}^{-3}$	Pryor & Meylan (1993)
Declination	−47.5°	Harris (1996)

5.2 The IMBH candidate and the mass tension

Evidence for a central dark mass in ω Cen has accumulated for two decades, from integrated kinematics (Noyola, Gebhardt & Bergmann 2008) through proper-motion modelling that initially yielded only upper limits at the $\sim 10^4\ M_\odot$ level (van der Marel & Anderson 2010), with stellar-mass black-hole subsystems long advanced as the alternative explanation (Zocchi, Gieles & Hénault-Brunet 2019; Breen & Heggie 2013). The situation changed qualitatively when Häberle et al. (2024a), using a proper-motion catalogue of 1.4 million stars built from over 500 HST epochs (Häberle et al. 2024b), identified seven stars within 3 arcsec of the cluster centre moving faster than the local escape velocity. Their velocities alone require a point mass $\geq 8{,}200\ M_\odot$; including acceleration limits on the same stars raises the lower bound to $21{,}100\ M_\odot$ at 99 per cent confidence (main text of Häberle et al. 2024a). Independent N-body modelling finds that an IMBH grown in situ to $\sim 5\times10^4\ M_\odot$ reproduces the present-day cluster structure and fast-star population (González Prieto, Rodriguez & Cabrera 2025).

Against this stands Bañares-Hernández et al. (2025): a joint analysis of stellar kinematics and timing accelerations of the cluster's millisecond pulsars that places a 3σ *upper* limit of $\sim 6\times10^3\ M_\odot$ on any central point mass, favouring instead an *extended* central dark component of ≈ 2–$3\times10^5\ M_\odot$ — naturally interpreted as a centrally concentrated cluster of stellar remnants. The two results are formally inconsistent under each side's stated modelling assumptions, and the disagreement is unresolved at the time of writing (Table 2). We take no side; for this paper the tension is itself the point. The MTH requires a genuine IMBH (P2), so the Bañares-Hernández scenario, if confirmed, falsifies the ω Cen application outright — one of several clean kill switches catalogued in Section 7. LISA will settle the question definitively: a single IMBH yields resolvable extreme-mass-ratio-inspiral (EMRI) signals with percent-level mass and spin measurement, whereas a remnant swarm yields a qualitatively different gravitational-wave signature (Amaro-Seoane 2018; Babak et al. 2017; Colpi et al. 2024).

Table 2. Current constraints on the central dark mass of ω Cen. The kinematic lower bounds and the pulsar-timing upper bound are mutually inconsistent under stated assumptions; resolution is expected from LISA EMRI observations and continued astrometry.

CONSTRAINT	VALUE	METHOD / SOURCE
Lower bound (velocities only)	$\geq 8{,}200\ M_\odot$	7 fast stars, HST proper motions (Häberle et al. 2024a)
Lower bound (with accelerations)	$\geq 21{,}100\ M_\odot$ (99%)	same stars, acceleration limits (Häberle et al. 2024a)
N-body growth models	$\sim 4.7\text{–}5.1 \times 10^4\ M_\odot$	cluster-evolution simulations (González Prieto et al. 2025)
Upper bound (point mass)	$< 6 \times 10^3\ M_\odot$ (3σ)	stellar kinematics + MSP timing (Bañares-Hernández et al. 2025)
Favoured alternative	extended $2\text{–}3 \times 10^5\ M_\odot$	same analysis (Bañares-Hernández et al. 2025)
Historical upper limits	$\lesssim 10^4\ M_\odot$ (model-dep.)	HST proper motions (van der Marel & Anderson 2010); see also Zocchi et al. (2019)

5.3 Electromagnetic silence

Whatever occupies the centre of ω Cen, it is extraordinarily dark. The deepest radio observation of any globular cluster — ~170 h with ATCA at 7.25 GHz, reaching an rms of 1.1 μJy beam^{-1} — detects nothing at any proposed cluster centre, bounding the accretion efficiency of a putative IMBH at $\varepsilon \lesssim 4 \times 10^{-3}$ of the Bondi rate (3σ) (Mahida et al. 2026). JWST NIRCam and MIRI photometry of the central field likewise finds no source with the spectral energy distribution of an accreting IMBH, with limits most constraining at the low-mass end of the allowed range (Chen et al. 2025). No dedicated technosignature search of ω Cen has ever been conducted at any wavelength; the first dedicated globular-cluster SETI survey (five northern clusters with FAST; ω Cen is inaccessible from FAST's latitude — Huang et al. 2026) demonstrates both the feasibility and the current emptiness of this niche.

We are emphatic about the logic here: electromagnetic silence is *predicted* by the MTH (P3–P4), but it is equally consistent with — and more parsimoniously explained by — a quiescent, gas-starved compact object in a relaxed, gas-poor old cluster, which we adopt as the null hypothesis H_0 throughout. Silence cannot confirm the MTH; only the discriminating residues of P4 can separate the hypotheses (Section 7).

5.4 Why not Sagittarius A*?

A natural objection: if bigger is better, the Galactic Centre hosts a $4.3\times10^6\ M_\odot$ hole (GRAVITY Collaboration 2022; Event Horizon Telescope Collaboration 2022) with abundant fuel. Three of the four selection criteria of Section 3.1 disfavour it. First, the storage and erasure advantages saturate at IMBH scale: nothing a maximizer needs scales usefully beyond $\sim10^{4-5}\ M_\odot$, while hazards do. Second, the Galactic Centre is the most dynamically violent environment in the Galaxy — ongoing star formation, supernovae, magnetar flares, stochastic accretion flares, and a dense population of perturbers — the opposite of a stable substrate for Gyr-scale infrastructure; ω Cen's relaxed core offers the same physics with none of the weather. Third, an uncontested claim matters: the Galactic Centre's gas and stars are the future fuel of natural astrophysics (and conceivably of competitors), whereas a globular cluster's low-mass stellar reservoir is, as noted, valueless to any fusion-era civilization. The MTH thus predicts that IMBHs in dense old clusters, not supermassive holes, are the preferred class — a distinctive and testable preference, since it directs attention at exactly the objects mainstream SETI has never examined.

6. A staged exploitation architecture

EPISTEMIC STATUS: This section is speculative civilizational engineering. It is included not as prediction but because the falsification program of Section 7 requires a concrete model of *what would be observable at each stage*. Each stage uses only physics established in Section 4 plus engineering extrapolations that are individually defended in the cited literature; the conjunction is unargued-for and carries the usual burden of compounded speculation.

We model the migration as five phases (Fig. 5), parameterized for a civilization departing a planetary system ~5 kpc from ω Cen.

Phase 1 — Scouts. Gram-scale beamed-sail probes at 0.1–0.2 c (Lubin 2016), with photon-braking and magnetic-sail deceleration into the cluster halo; transit ~10^5 yr. Objectives: resolve the IMBH-versus-swarm question in situ, map the rocky-body inventory, and emplace a deceleration relay for following waves. *External signature: none detectable at interstellar range.*

Phase 2 — Self-replicating industry. Kilogram-scale seed factories bootstrap exponentially from asteroidal material, following the NASA self-replicating-systems concept (Freitas & Gilbreath 1982); decades to centuries to 10^{3+} factory units and a relay laser. *Signature: waste heat of order early-industrial — far below detectability.*

Phase 3 — ISCO computronium swarm. The main payload (substrate-independent minds, by this stage the default cargo; cf. Smart 2012) arrives and assembles a free-flying compute swarm near the ISCO (1.8×10^5 km at 2×10^4 $M_\odot$, $a_\star \approx 0$). Controlled star-lifting of brown dwarfs establishes a thin sub-Eddington disk; BZ extraction begins at low spin. Tiered orbits allocate clock rate (Section 4.4). *Signature: faint, soft accretion luminosity — the one phase in which the system would be conventionally observable; at* ω *Cen, current limits (Mahida et al. 2026; Chen et al. 2025) already exclude an active Phase 3 above ~*10^{-3} *Eddington.*

Phase 4 — Spin-up. Sustained prograde feeding (~$10^{4\text{–}5}$ stars over ~10^8 yr; Section 4.1) drives $a_\star \rightarrow$ 0.9–0.998; the ISCO migrates inward by a factor ~5, jet efficiency crosses unity in MAD episodes, and the swarm follows the ISCO down. *Signature: secular cluster-core depletion; episodic jet activity if imperfectly managed; high spin as a permanent record.* We flag the strongest hidden premise of the whole architecture here: Phases 3–5 presuppose institutional or goal stability over 10^8 yr, longer than mammalian evolutionary history, and stellar feeding requires active orbit-shaping of individual stars with non-trivial delta-v budgets. We know of no principled argument that either is achievable; the architecture is offered conditional on both.

Phase 5 — Endpoint. Near-extremal spin; archive functions migrated to deep orbits at ~11:1 dilation; waste entropy disposed across the horizon (Section 4.2); residual stellar population dispersed or consumed. The system is thermodynamically silent: no infrared excess, no radio leakage, horizon temperature in the picokelvin range (Eq. 4), invisible against the CMB. The sole conjectured emission channel is burst-mode: if intractable computations are delegated to manufactured micro black holes per Dvali & Osmanov (2023), their evaporation yields high-energy neutrino and gamma-ray transients. We note for completeness that the formation of micro black holes from focused radiation may be blocked by Schwinger-limit pair production (Álvarez-Domínguez et al. 2024; Breit & Wheeler 1934; Schwinger 1951); this conclusion is contested (Loeb 2024), and the MTH does not depend on the channel — it affects only the strength of prediction T6 below.

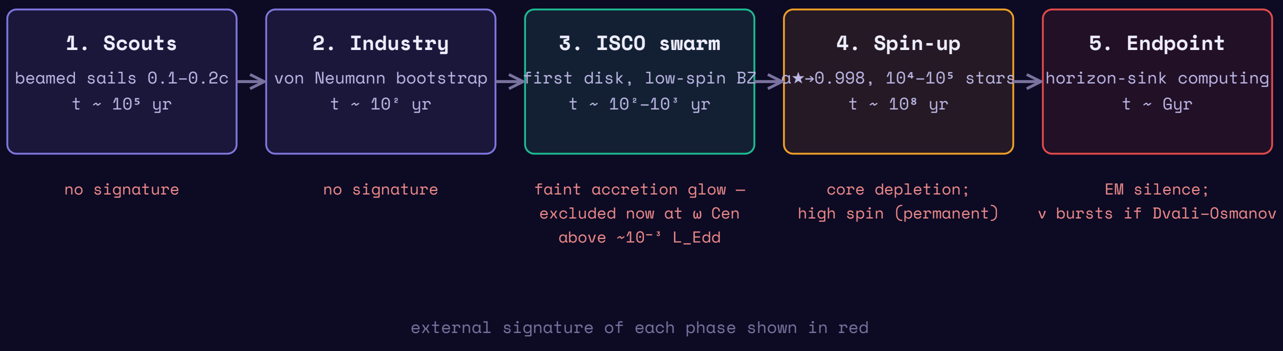

Figure 5. The five-phase exploitation architecture (speculative; see epistemic-status box) and the external signature of each phase. Only Phase 3 is conventionally luminous; the permanent observables are dynamical (spin, core depletion), which is why gravitational-wave spin measurement is the decisive test.

7. Falsification framework and observational program

A hypothesis earns scientific standing by what it risks. We define the competing hypotheses explicitly, then the tests.

> **H_0 (gas starvation; null).** The central object — whether IMBH or remnant swarm — is electromagnetically silent for the ordinary reason: a relaxed, gas-poor, 12-Gyr-old cluster supplies nothing to accrete. Favoured by parsimony and adopted as default.

> **H_1 (dark remnant swarm).** No IMBH exists; the central mass is an extended cluster of stellar remnants (Bañares-Hernández et al. 2025; Zocchi et al. 2019; Breen & Heggie 2013). Falsifies the ω Cen application of the MTH.

> **H_2 (MTH).** An IMBH exists and is, or has been, the substrate of a migrated civilization (Section

6).

H_0 and H_2 predict identical electromagnetic appearances today — by design, since P3–P4 entail silence — so electromagnetic non-detections cannot distinguish them. They diverge on dynamical and high-energy observables. Table 3 states six tests with thresholds, instruments, and timelines; Fig. 6 arranges the decisive subset as a decision tree.

Table 3. Falsification matrix for the MTH at ω Cen. "Kills" indicates what a positive result rules out; tests marked † are decisive against the hypothesis as a whole rather than against one phase. LISA timeline assumes launch in the mid-2030s (Colpi et al. 2024).

#	OBSERVATION	THRESHOLD	INSTRUMENT	TIMELINE	KILLS
T1	Accretion luminosity from core	$L_{acc} > 10^{29}$ W (~10^{-3} L_{Edd} at 2×10^{4} $M_\odot$) sustained >1 yr	JWST MIRI; ATCA/MeerKAT; Chandra	now–2030	Phase 5 (managed environment); already constrained (Mahida et al. 2026; Chen et al. 2025)
T2	Mid-IR waste-heat excess	>3σ over stellar-population model, 10–30 μm	JWST MIRI	now–2030	Any Dyson-type capture; Phases 4–5 (horizon-sink prediction is *zero* excess)
T3†	GW signature inconsistent with single point mass	stochastic background or multiple low-mass inspirals from core	LISA	late 2030s–2040s	H_2 entirely (confirms H_1); removes P2 substrate
T4†	EMRI point mass too small	clean chirp, $M < 5\times10^{3}$ $M_\odot$ at >3σ	LISA	late 2030s–2040s	H_2 at ω Cen: power budget insufficient ($P \propto M$, Eq. 2)
T5†	EMRI spin measurement low	$a_\star < 0.1$ at >3σ	LISA	late 2030s–2040s	The exploitation model: no BZ reservoir, no spin-up history; MTH survives only in unmodified "pre-arrival" form

#	OBSERVATION	THRESHOLD	INSTRUMENT	TIMELINE	KILLS
T6	High-energy neutrino bursts from core	≥3 tracks within 1° in $10^{2–3}$ s, E $\gtrsim$ 10 TeV, >5σ post-trials, no astrophysical counterpart	KM3NeT/ARCA (ω Cen is up-going from the Mediterranean; dec. −47°)	2026–2035	A null at full sensitivity closes the Dvali–Osmanov channel; a detection is consistent with (not proof of) H_2

Three features of this matrix deserve emphasis. First, it contains genuine kill switches: T3 and T4 falsify the ω Cen application outright, and T5 falsifies the only exploitation model we have offered. The MTH cannot survive a confirmed remnant swarm, a sub-5×10^3 $M_\odot$ point mass, or a non-spinning IMBH, except as vacuous speculation about other systems. Second, the single most informative number obtainable this generation is the *LISA spin measurement*: H_0 makes no strong spin prediction (natural IMBH formation channels span low-to-moderate spin), while a measured $a_\star \gtrsim 0.9$ on a gas-starved IMBH that has accreted nothing for Gyr would be difficult to explain naturally and is the MTH's flagship residue (P4a). EMRI parameter estimation at LISA delivers spin to better than percent precision for favourable systems (Babak et al. 2017; Amaro-Seoane 2018). Third, the program is cheap: T1–T2 are archival or piggyback analyses; T6 requires only a pointed monitoring program on an instrument already built for the southern sky (Adrián-Martínez et al. 2016; KM3NeT Collaboration 2025), following the high-energy SETI logic of Lacki & DiKerby (2025) and the pipeline practices of standard point-source searches (IceCube Collaboration 2020); and T3–T5 are free by-products of LISA's planned EMRI science (Colpi et al. 2024). A dedicated ω Cen technosignature campaign would be the first of its kind for any globular cluster beyond the pilot survey of Huang et al. (2026), which could not observe ω Cen.

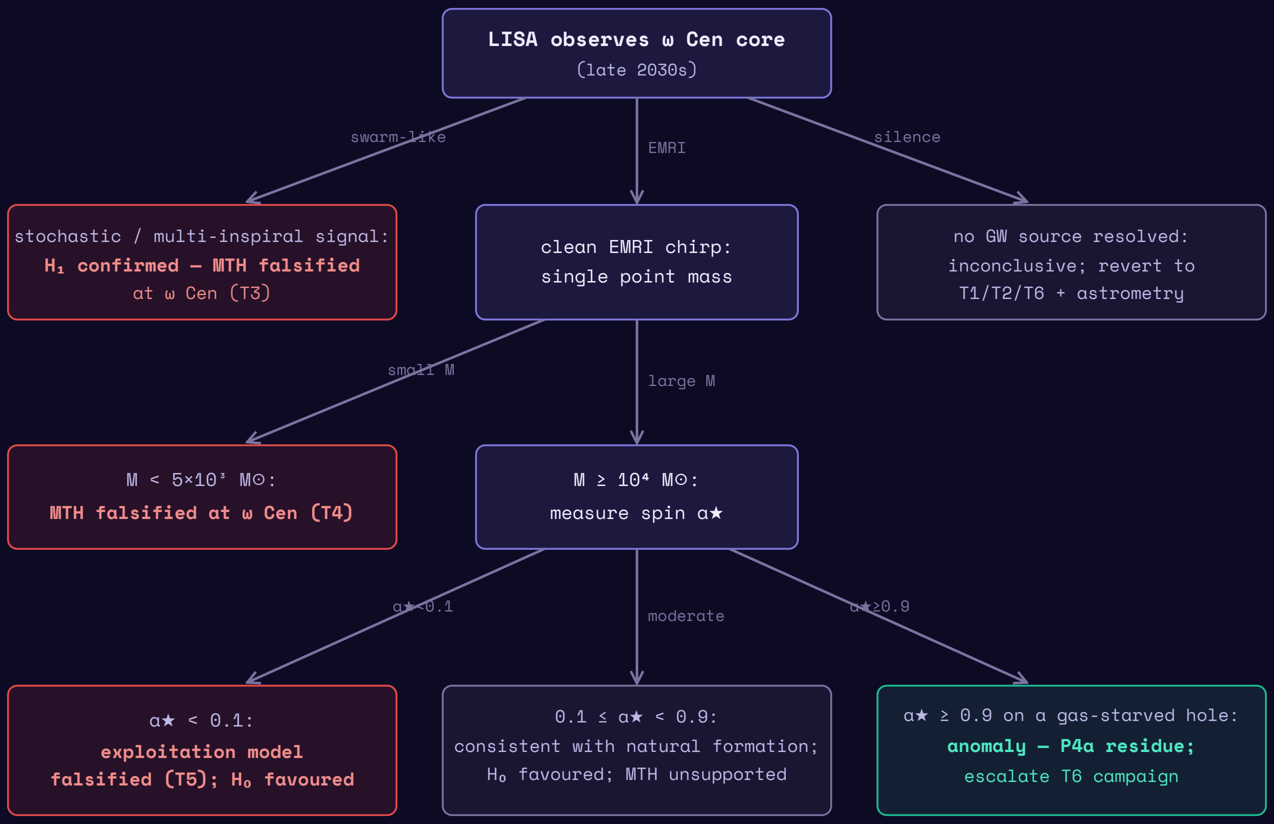

Figure 6. Decision tree for the decisive (gravitational-wave) branch of the falsification program. Red boxes terminate the hypothesis or its exploitation model; the single green branch is the only outcome in which the MTH gains material support, and even there the inference is to "anomaly requiring explanation," not detection.

7.1 What would count as support

Symmetry requires stating the confirmation side. The MTH gains support only from conjunctions that H_0 finds awkward: (i) a LISA-confirmed IMBH with $a_\star \gtrsim 0.9$ *despite* Gyr-scale gas starvation; (ii) repeated $>5\sigma$ neutrino bursts from the core with hard spectra and no electromagnetic counterpart, matching the Dvali–Osmanov phenomenology; or (iii) astrometric evidence of statistically anomalous depletion of loosely bound core stars relative to N-body expectations. No single line, including all three jointly, would constitute proof of technology; they would constitute an anomaly stack justifying escalated scrutiny, which is all a hypothesis of this kind can responsibly aim for. Conversely, we commit in advance: if LISA delivers T3, T4, or T5, the ω Cen application of the MTH should be retired without special pleading.

8. Discussion: objections and limits

Parsimony. The MTH posits extraterrestrial intelligence; H_0 posits nothing. By any reasonable prior the null is favoured, and we have structured every comparison accordingly. The defensible claim is not that the MTH is probable but that it is *cheap to test relative to its information value*: it concentrates the diffuse question "where is everybody?" onto a handful of named objects and a decade-scale instrument schedule, and its decisive observables (IMBH reality, mass, spin) are independently first-rank astrophysics that will be measured anyway.

The anthropic objection. If P1–P2 captured all civilizations, our own existence as a young, loud, planet-bound species is unremarkable; the MTH explains the silence of the old, not the existence of the young. It is therefore not undermined by our own counterexample, but neither can it explain why *no* expansionist civilizations are visible (cf. Hanson et al. 2021): if migration is optional, loud lineages should still exist somewhere. The honest position is that the MTH thins the expected population of loud civilizations by removing its most capable members, sharpening rather than fully dissolving the paradox — full dissolution requires either high migration compliance or supplementary rarity from conventional Drake-equation factors.

Goal stability over 10^8 years. Phase 4 presupposes coherent purpose across timescales that dwarf all institutional experience. We flagged this as the architecture's largest unargued premise (Section 6). One partial mitigation: the architecture's payoff structure is front-loaded (Phase 3 already yields a substrate orders of magnitude beyond planetary computing), so a lineage that fragments mid-program still leaves the P4 dynamical residues that our tests target. The observational program is thus robust to civilizational incoherence even where the full architecture is not.

Tidal and radiative survivability at the ISCO. At $2\times10^4\ M_\odot$ the tidal field at the Schwarzschild ISCO is $2GM/r_{ISCO}^3 \approx 1\ s^{-2}$: a 10-m node experiences a benign ~1 g differential, while kilometre-scale rigid structures would face $\sim10^2$ g — one reason the architecture assumes a swarm of small free-flying nodes rather than a monolithic platform. Radiation from even a managed accretion disk is the harsher constraint, and motivates the tiered-orbit design and sub-Eddington feeding discipline assumed in Section 6.

Why has nothing arrived here? A migration hypothesis must explain why migrators' probes are not conspicuous in every system, reviving Hart (1975) and Tipler (1980). The MTH answer is economic:

for a computation-maximizer, planetary systems are not destinations but at most transit infrastructure; the observable universe contains ~10^{9} times more free energy in uncollected starlight than any single system is worth, and yet (Section 4.5) the marginal value of *any* outward claim is dominated by deepening the home gravity well. Quiet, minimal, purpose-built transit — not occupation — is the predicted footprint, consistent with the null results of artefact SETI to date (Wright et al. 2022).

The kugelblitz weak link. The only positive high-energy signature we predict (T6) inherits the controversy over micro-black-hole formation from radiation (Álvarez-Domínguez et al. 2024; Loeb 2024). We therefore weight T6 as the cheapest test, not the strongest: its null closes a speculative channel; its detection would be extraordinary but stands or falls with Dvali–Osmanov physics, not with the MTH core.

Scope of the ω Cen bet. The MTH is a selection theory over a class; ω Cen is its highest-ranked accessible member, not its definition. Falsification at ω Cen (T3/T4) retires the flagship application and substantially weakens the hypothesis — the Galaxy's best candidate failing is evidence about the class — but formally the theory survives in 47 Tuc, M54, and extragalactic nuclear clusters. We accept the methodological hazard this creates (unfalsifiability by retreat) and therefore bind ourselves to the class-level prediction: *if no Galactic globular-cluster IMBH with* $a_\star \gtrsim 0.9$ *exists, the MTH is wrong for the Milky Way*, a statement LISA-era gravitational-wave astronomy can settle.

9. Conclusion

We have argued, first as a matter of established physics, that rapidly spinning massive black holes in dense old stellar clusters constitute the global optimum among present-day environments for long-term computation — by factors of ~10^{2} in energy per unit fuel, ~10^{9} in continuous power, ~10^{12} in entropy-disposal cost, and unbounded factors in archival density — and second, as an explicitly speculative hypothesis, that this gradient acts on the oldest technological civilizations as an attractor whose operation would look, from outside, exactly like the silence we observe. The Macro Transcension Hypothesis inherits the thermodynamic insight of transcension and aestivation while repairing their respective defects: it needs no exit from the universe and no dormancy, and it survives the Bennett–Hanson–Riedel free-energy objection by importing the cold reservoir into the present rather than waiting for one.

Its principal virtue is that it pays its way observationally. The hypothesis selects a named target — Omega Centauri, whose contested 8×10^3–5×10^4 $M_\odot$ central object, perfect electromagnetic silence, and 12-Gyr head start make it scientifically urgent on entirely conventional grounds — and commits to kill criteria that existing and funded instruments will adjudicate: LISA's resolution of the IMBH-versus-swarm question and, above all, its spin measurement; deep accretion and waste-heat limits from JWST and southern radio arrays; and a first-of-its-kind neutrino monitoring campaign with KM3NeT. If the central object proves to be a remnant swarm, a light point mass, or a slowly spinning hole, the hypothesis fails at its flagship and we have said so in advance. If instead the 2030s deliver a massive, gas-starved, near-extremally spinning black hole in the quietest old cluster in the sky, the question this paper poses will have earned the right to be taken seriously.

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