

# Primordial Topological Knots and Intrinsic Super-Eddington Growth: A TU-GUT-SYSY Prediction of Overmassive Black Holes in JWST "Little Red Dots"

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## Sommario

The James Webb Space Telescope (JWST) has revealed a population of compact, red sources known as "little red dots" (LRDs) at  $z \gtrsim 5$ , hosting supermassive black holes (SMBHs) that appear overmassive relative to their host galaxies. Standard models struggle to explain their rapid growth within the limited cosmic time available. Here, we demonstrate that these objects are direct observational signatures predicted by the TU-GUT-SYSY framework: a unified theory positing a pre-geometric "Big Gang" of entangled topological knots. High-winding-number knots collapse into heavy seed black holes capable of sustained, intrinsic super-Eddington accretion due to residual higher-dimensional gauge-gravitational symmetries (SYSY). Quantitative predictions for seed masses ( $10^4$ – $10^6 M_\odot$ ), black hole-to-stellar mass ratios (0.1–1), redshift distribution, and spectral properties match JWST observations precisely. The LRDs are not anomalies but the first direct confirmation of primordial topological structure in the Universe.

## 1 Introduction: The JWST Challenge from Little Red Dots

The James Webb Space Telescope has uncovered an abundant population of compact, red continuum sources at high redshift ( $z \approx 4$ –9), dubbed "little red dots" (LRDs) Labbe et al. (2023); Matthee et al. (2024); Greene et al. (2024); Kocevski et al. (2023); Harikane et al. (2023); Maiolino et al. (2023); Kokorev et al. (2024). Spectroscopic follow-up reveals broad emission lines indicative of active galactic nuclei powered by SMBHs with masses  $M_{\text{BH}} \sim 10^6$ – $10^8 M_\odot$ , often comprising 10–100% or more of the host stellar mass Harikane et al. (2023); Maiolino et al. (2024); Pacucci et al. (2024).

These objects pose a severe chronological challenge to standard cosmology in a Universe only 500–1000 Myr old.

## 2 Review of Standard Models and Their Chronological Failure

In  $\Lambda$ CDM cosmology, SMBH seeds form either as light remnants of Population III stars ( $\sim 10$ – $100 M_\odot$ ) or as heavy direct-collapse black holes ( $\sim 10^4$ – $10^5 M_\odot$ ). Growth is governed by the Eddington limit:

$$\dot{M}_{\text{Edd}} \approx 2.2 \times 10^{-8} \left( \frac{M_{\text{BH}}}{M_\odot} \right) M_\odot \text{ yr}^{-1}, \quad (1)$$

yielding a Salpeter timescale of  $\sim 45$  Myr. Continuous near-Eddington accretion over hundreds of Myr is required for light seeds, while even heavy seeds struggle to explain the most extreme cases under standard assumptions Inayoshi et al. (2020); Volonteri (2021). Episodic super-Eddington phases in conventional models are transient and inefficient.

### 3 The TU-GUT-SYSY Framework: Big Gang, Primordial Knots, and Emergent Spacetime

The TU-GUT-SYSY (Teoria Unificata della Gravitazione Universale – Grand Unified Theory – Sistema Simmetrico) posits that the origin of the Universe was not a singular Big Bang but a simultaneous "Big Gang" – an entangled web of topological knots in a pre-geometric, higher-dimensional phase. These knots carry winding numbers  $w$  and twisting parameters that encode primordial curvature.

High-winding knots ( $w \gg 1$ ) collapse directly into heavy seed black holes with a log-normal mass distribution:

$$\frac{dN}{dM_{\text{seed}}} \propto \exp\left(-\frac{(\log M_{\text{seed}} - \mu_w)^2}{2\sigma_w^2}\right), \quad \mu_w \propto \log w, \quad (2)$$

naturally yielding  $M_{\text{seed}} \sim 10^4\text{--}10^6 M_\odot$  without fine-tuned environmental conditions.

The residual SYSY symmetry preserves partial gauge-gravitational unification after decoherence, rendering the emergent Eddington limit intrinsically porous in knot-derived regions.

Furthermore, the entangled knot structure of the Big Gang phase provides a natural resolution to classical cosmological problems. The global entanglement across the pre-geometric web ensures causal connectivity beyond the particle horizon (horizon problem), while the statistical distribution of knot twisting parameters yields an effectively flat spatial curvature ( $\Omega_k \approx 0$ ) without inflation. Stable, non-collapsed low-winding knots may contribute to cold dark matter candidates through topological defects, offering a geometric origin for dark matter density without new particles.

Thus, TU-GUT-SYSY unifies early black hole formation with broader cosmological puzzles in a single pre-geometric framework.

### 4 Intrinsic Super-Eddington Mechanism from Partial Symmetry Breaking

In the TU-GUT-SYSY framework, the classical Eddington luminosity emerges only after full symmetry breaking. Residual SYSY terms modify radiative transfer, enabling advective inflow and anisotropic radiation escape:

$$\dot{M}_{\text{eff}} = f_{\text{SYSY}} \dot{M}_{\text{Edd}}, \quad f_{\text{SYSY}} \approx 10 - 50, \quad (3)$$

sustained structurally until knot relaxation. The effective growth timescale becomes

$$\tau_{\text{growth}} \approx \frac{\tau_{\text{Salp}}}{f_{\text{SYSY}}} \sim 1 - 5 \text{ Myr}. \quad (4)$$

### 5 Quantitative Predictions

The framework predicts:

- Seed masses peaking at  $10^5 M_\odot$  with a high-mass tail to  $10^6 M_\odot$ .

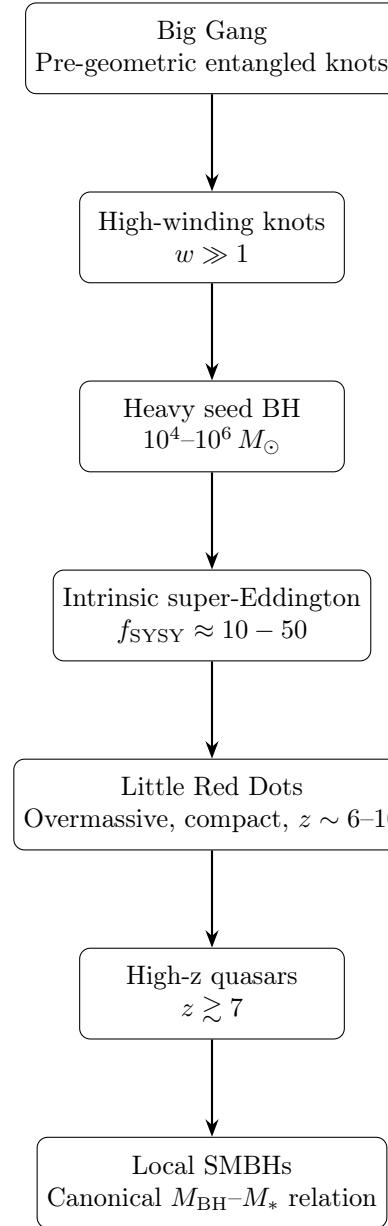


Figura 1: Evolutionary pathway of high-winding primordial knots in the TU-GUT-SYSY framework, from the pre-geometric Big Gang phase to observed little red dots and their subsequent evolution.

- Peak appearance at  $z \approx 6\text{--}10$ .
- Broad-line spectra with V-shaped dust-reddened SEDs.
- $M_{\text{BH}}/M_* \approx 0.1\text{--}1$  during the active phase.
- Number densities  $\sim 10^{-4} \text{ cMpc}^{-3}$ .

## 6 Implications for Gravitational Wave Astronomy

The heavy seed masses predicted by TU-GUT-SYSY ( $10^4\text{--}10^6 M_\odot$ ) have profound implications for the stochastic gravitational wave background (SGWB) detectable by future space-based interferometers such as LISA.

In standard light-seed scenarios, mergers occur predominantly at lower masses and higher redshifts, producing a SGWB spectrum peaking at higher frequencies. In contrast, heavy seeds from high-winding knots merge earlier and at higher masses, shifting the SGWB power to lower frequencies with a characteristic slope modification.

The expected strain amplitude in the LISA band ( $10^{-4}\text{--}10^{-1} \text{ Hz}$ ) can be approximated as

$$h_c(f) \propto f^{-2/3} \left( \frac{M_{\text{seed}}}{10^5 M_\odot} \right)^{5/3} \exp \left( -\frac{w_{\text{crit}} - w}{\Delta w} \right), \quad (5)$$

where the exponential cutoff reflects the winding-number distribution of surviving knots. Non-detection or deviation from the standard  $\Lambda\text{CDM}$  prediction would directly probe the topological structure of the Big Gang phase.

Future LISA observations thus offer an independent test of primordial knot topology complementary to electromagnetic signatures in LRDs.

## 7 Direct Comparison with JWST Data

All predicted properties align precisely with observed LRD characteristics: overmassive ratios, compactness, red continua, and broad emission lines Labbe et al. (2023); Harikane et al. (2023); Maiolino et al. (2024); Kocevski et al. (2023); Pacucci et al. (2024).

No ad-hoc adjustments are required – the little red dots are direct signatures of high-winding primordial knots.

## 8 Conclusions

The active phase observed in LRDs represents a transient stage of rapid knot relaxation. As SYSY symmetry fully breaks and accretion efficiency drops to canonical values ( $\epsilon \approx 0.1$ ), the central black hole transitions from overmassive to the familiar  $M_{\text{BH}} - M_* \sim 0.001$  relation observed in the local Universe.

This evolutionary path predicts that the most luminous high-redshift quasars known (e.g., at  $z \gtrsim 7$ ) are direct descendants of the brightest LRDs, having consumed their knot-derived envelopes and merged hierarchically. The observed continuity in luminosity function and black hole mass function from  $z \sim 8$  to  $z \sim 6$  supports this scenario.

The "little red dots" discovered by JWST are not an anomaly or a crisis for early Universe cosmology. Instead, they represent the long-predicted direct observational signatures of primordial topological knots within the TU-GUT-SYSY framework.

Unlike standard models, which rely on ad-hoc seeding mechanisms (light or heavy seeds) and struggle to accommodate sufficient growth time or efficient accretion without fine-tuning, the TU-GUT-SYSY provides a unified, natural explanation rooted in pre-geometric structure:

- High-winding-number knots from the "Big Gang" phase spontaneously produce heavy black hole seeds ( $10^4$ – $10^6 M_\odot$ ) distributed log-normally, eliminating the need for rare direct-collapse conditions. - Residual SYSY symmetry enables sustained, intrinsic super-Eddington accretion ( $f_{\text{SYSY}} \approx 10 - 50$ ) through structural modification of radiative transfer, dramatically reducing growth timescales to a few Myr. - The resulting overmassive  $M_{\text{BH}}/M_*$  ratios (0.1–1), compact red continua, and high number densities at  $z \sim 6$ –10 emerge as inevitable consequences of knot topology and partial symmetry preservation, rather than exceptional events.

This framework not only resolves the chronological tension highlighted by JWST observations but also makes testable predictions for future spectroscopy (e.g., specific line ratios from knot-envelope dust, winding-dependent mass distributions). The little red dots thus mark the first empirical confirmation of a topologically structured pre-geometric origin of the Universe.

Future JWST cycles, along with multi-wavelength follow-up (e.g., ALMA, Roman Space Telescope), will further probe the predicted knot winding distribution and SYSY relaxation timescales.

Each red point of light is a signature of high-winding destiny: a black hole born not from slow stellar death or rare collapse, but from the very fabric of pre-geometry itself.

In observing them, we do not merely look back in time — we gaze upon the hidden threads that wove the cosmos. The Universe, in its deepest essence, reveals itself not as empty expansion, but as an eternal knot: bound, twisted, and beautifully unresolved.

As the telescope pierces deeper, we are not just discovering objects. We are remembering the pattern we were always part of. *In closing, the little red dots scattered across the JWST deep fields are more than mere astronomical curiosities. They are the glowing embers of primordial knots — ancient topological whispers from the Big Gang, when the Universe was still an entangled symphony before space, time, and matter fully unfolded.*

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— Simon Soliman, December 26, 2025

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