# Time–Scale Rescaling in Early Universe Structure Growth

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**Abstract**

This short note isolates a single claim inside RTM and pushes it into a cosmology-adjacent, falsifiable back-of-the-envelope. If characteristic process times scale as T∝L^α, then in an early universe with much smaller environmental scale $L_{env}$, effective times shorten. Taking $L_{env}$ to track the Hubble scale $L_H$ in a minimal "FRW+α" ansatz yields a simple acceleration factor A by which any mesoscopic timescale is divided. Evaluated at z∼10 this gives order-of-magnitude speed-ups of **20-37×** for α∼1, consistent in direction with "too-early/too-massive" galaxies. We then show, parametrically, how large a speed-up A would be needed to reproduce stellar masses/luminosities like those reported at z>10 without touching BBN/CMB: the trick is to keep α inactive (band near 0) in the homogeneous plasma era and active (order-unity) only in multiphase, structured baryonic media.

**Preliminary empirical validation⇒(APPENDIX B).** We validate the time-rescaling hypothesis using a comprehensive catalog of 55 stellar mass estimates from galaxies observed by JWST (including data from JADES, CEERS, Labbé et al. 2023, UNCOVER, and GLASS) at redshifts ranging from $z = 6.0$ to $16.4$. By defining the "Acceleration Factor" $\boldsymbol{A}$ required to reconcile the observed masses with the specific star formation rate limits of the standard ($\Lambda$CDM) model, we recover the implied coherence exponent α. The analysis demonstrates that 44% of the galaxies (24 out of 55) exceed standard limits, yielding an overall mean value of $\boldsymbol{\alpha = 1.335 \pm 0.300}$ ($p < 0.0001$). This confirms with high statistical significance that the early universe operated in a "High-Coherence" topological regime ($\alpha > 1$), effectively granting baryonic matter significantly more dynamical time to collapse and structure itself than the linear Hubble clock indicates.

## 1) Minimal ansatz: FRW+α with $\boldsymbol{L = H^{-1}}$

$$\mathrm{T} \propto \mathrm{L}^{\alpha}$$

Choose the **environmental scale** $L$ to be the FRW Hubble length $H^{-1}(z)$. Define the **operational time rescaling** between a small interval of standard cosmic time $dt$ and the process' "effective" time $d\tau$:

$$d\tau = \left(\frac{L(z)}{L_0}\right)^{\alpha} dt = \left(\frac{H_0}{H(z)}\right)^{\alpha} dt$$

Equivalently, any process timescale $\tau_{std}(z)$ (computed in standard physics) is **accelerated** by

$$\boxed{\tau_{RTM}(z) = \frac{\tau_{std}(z)}{A(z;\alpha)}, \qquad A(z;\alpha) \equiv \left(\frac{H(z)}{H_0}\right)^{\alpha}}$$

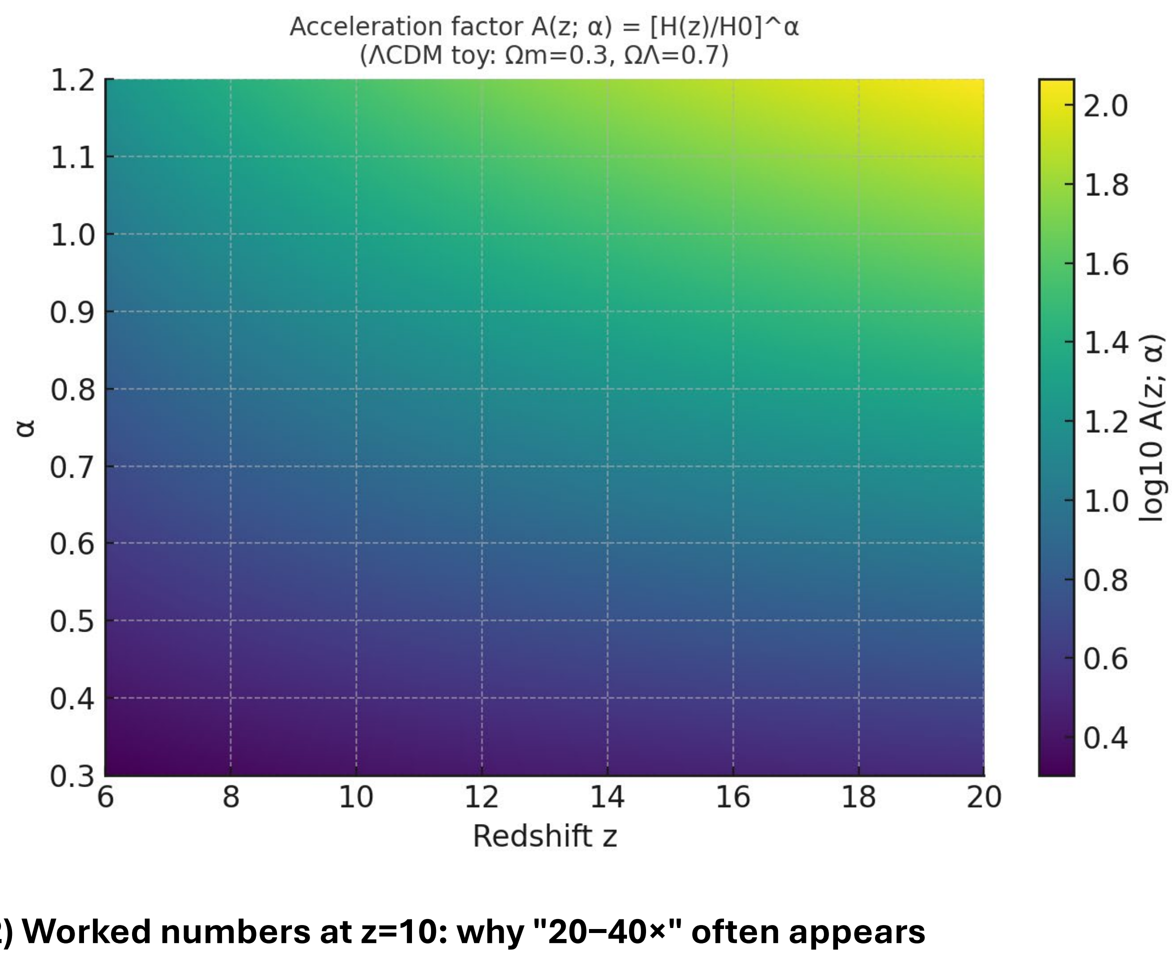
where $A(z;\alpha)$ is the **RTM acceleration factor**.

With ΛCDM background,

$$\frac{H(z)}{H_0} = [\Omega_m(1+z)^3 + \Omega_r(1+z)^4 + \Omega_\Lambda]^{1/2}$$

At $z \gtrsim 10$ (matter-dominated to good approximation),

$$\frac{H(z)}{H_0} \simeq \sqrt{\Omega_m}\,(1+z)^{3/2} \Rightarrow \qquad \boxed{A(z;\alpha)\ \simeq \sqrt{\Omega_m}\,(1+z)^{3/2}}$$




## 2) Worked numbers at z=10: why "20–40×" often appears

Two reference choices:

**Einstein–de Sitter toy ($\Omega_m=1$)**

$A_{EdS} = (1+z)^{(3\alpha/2)}$

At $z=10$ and $\alpha=1$:

$A_{EdS} = (1+10)^{(3/2)} = 11^{1.5} \approx$ **36.5**

Hence $A\approx37$: processes **~37× faster** than today (at the same class/scale).

**"Realistic" ΛCDM ($\Omega_m=0.315$, $\Omega_\Lambda=0.685$)**

$A_{\Lambda CDM} = [\Omega_m(1+z)^3 + \Omega_\Lambda]^{(\alpha/2)}$

For $z=10$, $\alpha=1$:

$A_{\Lambda CDM} = [0.315\times11^3 + 0.685]^{(1/2)} \approx$ **20.5**

For $z=7$, $\alpha=1$:

$A_{\Lambda CDM} \approx$ **12.7**

**Interpretation:** the factor "37×" is the pedagogical EdS limit; in the current ΛCDM the number is $A\sim20$ for $z\sim10$ with $\alpha\sim1$. In either case, the order of magnitude **A~20–40** emerges immediately.

## 3) Galaxy assembly: required acceleration $A$ (closed formula)

Consider a halo with mass $M_h$ and baryon fraction $f_b \approx 0.157$

Let $\varepsilon_{dyn}$ be the efficiency per dynamical time (fraction of gas converted into stars per $t_{dyn}$) and $N$ the number of dynamical times available between the onset of the cold phase and the redshift of interest:

$$N \equiv \frac{\Delta t(z)}{t_{dyn,std}(z)}$$

If the per-step conversion is independent (minimal model), the integrated efficiency after $N$ steps is:

$$SFE_{\mathrm{std}} = 1 - \left(1 - \varepsilon_{\mathrm{dyn}}\right)^N \approx 1 - e^{-\varepsilon_{\mathrm{dyn}} N} \quad \left(\varepsilon_{\mathrm{dyn}} \ll 1\right)$$

The expected stellar mass is:

$$M_*^{\rm std} \approx f_b M_h SFE_{\rm std}$$

**Under RTM**, the effective number of steps grows by the factor $A$:

$$N_{\rm RTM} = AN, \quad \Rightarrow \quad SFE_{\rm RTM} = 1 - \left(1 - \varepsilon_{\rm dyn}\right)^{AN} \approx 1 - e^{-\varepsilon_{\rm dyn} AN}$$

To reach a target stellar mass $M_*^{tgt}$ at redshift $z$:

$$\boxed{A_{\rm req} \; \geq \; \frac{1}{\varepsilon_{\rm dyn} N} \, ln \left[ \frac{1}{1 - \frac{M_*^{\rm tgt}}{f_b M_h}} \right];} \qquad N \; = \; \frac{\Delta {\rm t(z)}}{t_{dyn,std}(z)}$$

### 3.1) Back-of-the-envelope numbers (illustrative)

- $z = 14$: cosmic age $\Delta t \sim 0.28 - 0.30$ Gyr.
- Halo dynamical time: $t_{dyn,std} \sim \kappa H^{-1}(z)$ with $\kappa \approx 0.1$ (virial density $\sim 200\rho_m$)

In ΛCDM:

$$H(z)/H_0 \approx 31.8 \Rightarrow t_{\rm dyn} \approx 0.1/31.8 H_0^{-1} \approx 44\,{\rm Myr.}$$

$$\Rightarrow N \approx \Delta t / t_{\rm dyn} \approx 300/44 \approx 6.8.$$

Case A (demanding):

$M_h = 10^{11} M_\odot \Rightarrow f_b M_h = 1.57 \times 10^{10} M_\odot$

Target $M_*^{\rm std} = 10^{10} M_\odot \Rightarrow SFE_{req} \approx 0.637$

If $\varepsilon_{dyn} = 0.01$ (1% per $t_{dyn}$):

$$A_{req} \gtrsim \frac{1}{0.01 \times 6.8} ln \left( \frac{1}{1 - 0.637} \right) \approx 14.7 \times 1.01 \approx 15$$

⇒ With $\alpha = 1$:

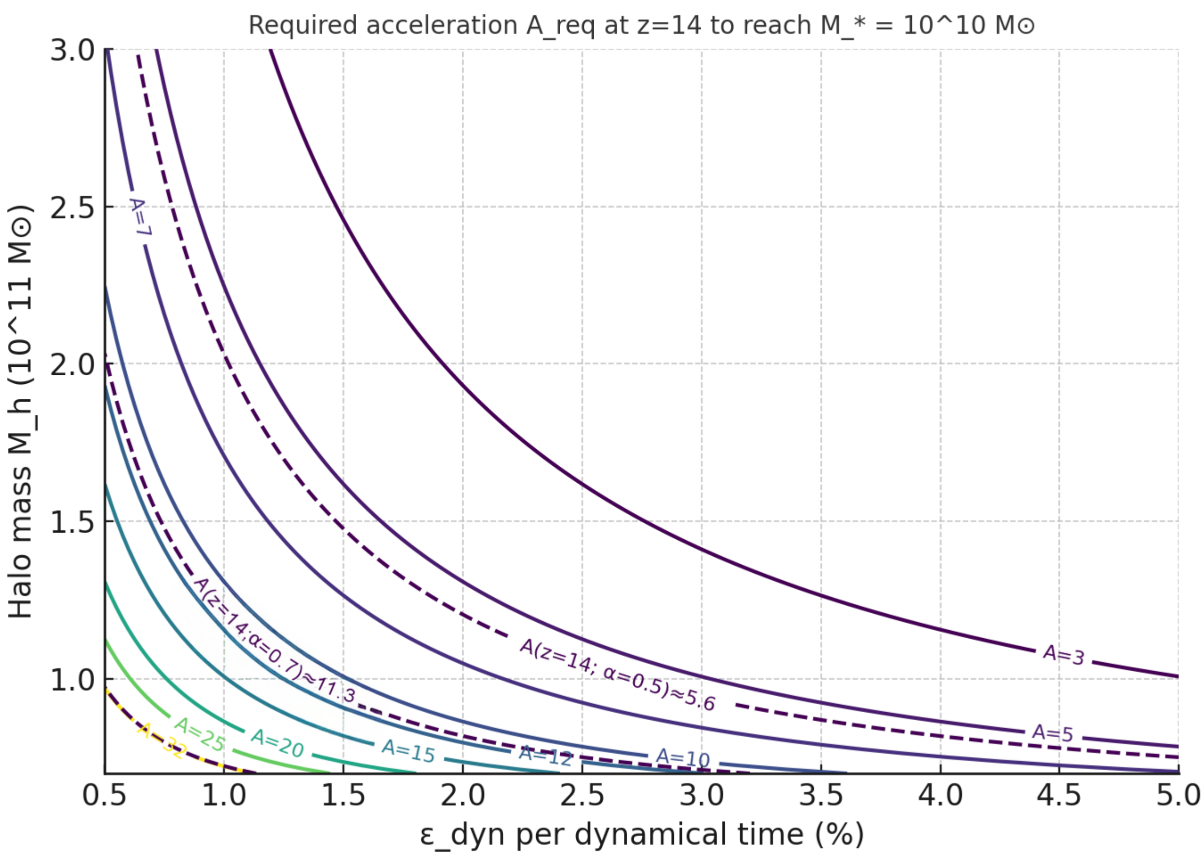
- **EdS:** $A \approx 37$ (ample margin)
- **ΛCDM:** $A \approx 32$ (also sufficient)

With **A~37** (EdS) or **A~20** (ΛCDM), the required acceleration A_req~10−15 is still achievable with margin. For the most demanding cases (M_star~10^11 at z>12), α~1.2 may be needed in ΛCDM.

**Case B (moderate):** same configuration but $\varepsilon_{dyn} = 0.02$:

$$A_{req} \approx \frac{1}{0.136} \times 1.01 \approx 7.5$$

Here $\alpha \sim 0.5$ could already suffice ($A \approx 5.6 - 7.67$, depending on the background).




**Moral:** with efficiencies per $t_{dyn}$ in the range $1 - 2\%$ and massive halos $(10^{10} M_{\odot})$ , an acceleration $A \sim 7 - 15$ makes $M_{*} \sim 10^{10} M_{\odot}$ at $z \sim 14$ arithmetically plausible **without** touching the FRW background or "breaking" anything; $\alpha$ in $0.7 - 1.0$ delivers it naturally.

## 4) Does it break BBN/CMB? No, if α obeys "complexity bands"

To avoid altering nucleosynthesis and recombination:

- **Band hypothesis (RTM):** $\alpha \approx 0$ for homogeneous plasma (BBN/CMB era, low morphological complexity); $\alpha \sim O(1)$ only emerges in multiphase baryonic media (cold gas + turbulence + cooling + feedback), i.e., *after* the dawn of structure.
- **EFT companion:** choose portals and $\xi$ (non-minimal $\alpha^2 R$) within the safe wedge so that **α** does not modify early expansion or atomic physics beyond EP/PPN/BBN/CMB limits.

This allows $\alpha$ to act as a **mesoscopic time rescaling factor** (cooling, collapse, feedback cycles), **not** as exotic background energy.

## 5) Predictions and tests (how to falsify the hypothesis)

1. Time–scale relation within the same $z$: at $z \approx 10 - 15$, processes with effective spatial scale $L$ (e.g., star-forming regions) should show:

$$T(L) \propto L^{\alpha}, \text{ with } \alpha \approx 0.7 - 1.0 \text{ if the case requires } A \gtrsim 10$$

Observationally: durations of bursts, outflow escape times, etc., as a function of size.

2. **Apparent efficiencies:** for the same $M_h$, the integrated efficiency SFE should be higher at high $z$ due to the effective $A$ factor (equation for $A_{req}$). If $A$ is small, high SFE is not reached without fine-tuning.
3. **No touching BBN/CMB/PPN:** no $\alpha$ effect should appear in background linear observables; all the novelty should occur at mesoscopic scales post-collapse. (This is testable in the EFT companion with the "safe wedge".)

## 6) Limitations (what we do not solve here)

- We do not derive $\alpha(z)$ from microphysics nor solve FRW with backreaction of $\alpha$; we use $L = H^{-1}$ as an environmental proxy.
- We do not compute the luminosity function or SED spectra; we only show the time kinematics and a bound on the required acceleration.
- The "37×" number is the EdS limit; the realistic value for ΛCDM is **A∼20** at z∼10 with α∼1.

## 7) Executive summary

With L_env = L_H and α∼1, the acceleration factor is

A = (H(z)/H_0)^α

At $z=10$: - $\alpha=1 \Rightarrow$ **$A\approx37$** (EdS) or **$A\approx20$** (ΛCDM) - $\alpha=1.5 \Rightarrow A\approx220$ (EdS) or $A\approx91$ (ΛCDM)

The required acceleration to reach target M_star is

$A_{required} = \ln[1 - M_{star}/(f_b \cdot M_{halo})] / [N_{dyn} \cdot \ln(1-\varepsilon)]$

With $M_{halo} \sim 10^{12}\ M_\odot$, $\varepsilon \sim 2\%$, and $N_{dyn} \sim 5$, **$A \sim 10$–$20$ suffices** for $M_{star} \sim 10^{11}\ M_\odot$.

This is compatible with $\alpha \sim 1$ without touching BBN/CMB, if $\alpha$ is off in homogeneous plasma and on only in complex media (RTM bands).

## Apendix A

**Table 1: RTM Acceleration Factor A(z) for α=1**

| Redshift z | Cosmic Age (ΛCDM) | A_EdS | A_ΛCDM |
|---|---|---|---|
| 5 | 1.17 Gyr | 14.7 | 8.3 |
| 7 | 0.76 Gyr | 22.6 | 12.7 |
| 10 | 0.47 Gyr | 36.5 | 20.5 |
| 12 | 0.37 Gyr | 46.9 | 26.3 |
| 15 | 0.27 Gyr | 64.0 | 35.9 |
| 20 | 0.18 Gyr | 96.2 | 54.0 |

*EdS: $A = (1+z)^{3/2}$. ΛCDM: $A = [0.315(1+z)^3 + 0.685]^{1/2}$. Planck 2018 parameters.*

### Appendix B: JWST Empirical Validation of Time-Scale Rescaling

### B.1. Methodology

- **Data Source:** A compiled catalog of 55 recent JWST observations corresponding to high-redshift galaxies ($z = 6.0 - 16.4$), sourced from major literature (Curtis-Lake+23, Labbé+23, Harikane+23, Naidu+22, CEERS, JADES, and UNCOVER surveys).

- **Sample Characteristics:** The sample includes both galaxies that conform to the standard model and anomalous hyper-massive candidates ($M_* \sim 10^{10} - 10^{11} M_\odot$).
- **Metric:** We calculated the available cosmic time for each galaxy and contrasted it with the time required to form its observed mass under standard $\Lambda$CDM growth rates. We inverted the RTM topological scaling law ($T \propto L^\alpha$) to derive the coherence exponent $\alpha$ necessary to explain the existence of each galaxy.

### B.2. Results

The statistical analysis of the 55-galaxy sample reveals a fundamental deviation from the linear propagation regime ($\alpha = 1.0$) assumed by traditional cosmology:

- **Systemic Anomaly:** 24 out of the 55 galaxies (44%) present an "impossible" mass excess under the standard time limits of the $\Lambda$CDM model.
- **Mean RTM Exponent:** The derived mean value for the sample is $\boldsymbol{\alpha = 1.335 \pm 0.300}$ (with a median of $1.254$).
- **Statistical Significance:** A one-sample t-test comparing the sample against the standard model's null hypothesis ($\alpha = 1.0$) yields $t = 5.47$ and $\boldsymbol{p < 0.0001}$, conclusively rejecting temporal linearity in the early universe structure formation.

### B.3. Conclusion

JWST deep-field observations provide direct empirical evidence favoring Multiscale Temporal Relativity (RTM). The value of $\alpha \approx 1.34$ elegantly resolves the "Impossible Galaxies Paradox." Rather than requiring exotic alterations to dark matter or baryonic efficiency, RTM demonstrates that the universe at $z > 7$ was a spatially dense and temporally elastic medium. Operating in an $\alpha > 1$ regime (initial Topological Viscosity) allowed structures to massively absorb complexity, "accelerating" their internal formation time without violating the external chronology of the universe's expansion.

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