A Black Hole Mass Threshold Framework for Bimodal Early Galaxy Evolution: Insights from JWST's JADES-GS-z14-0 (Revised Version)

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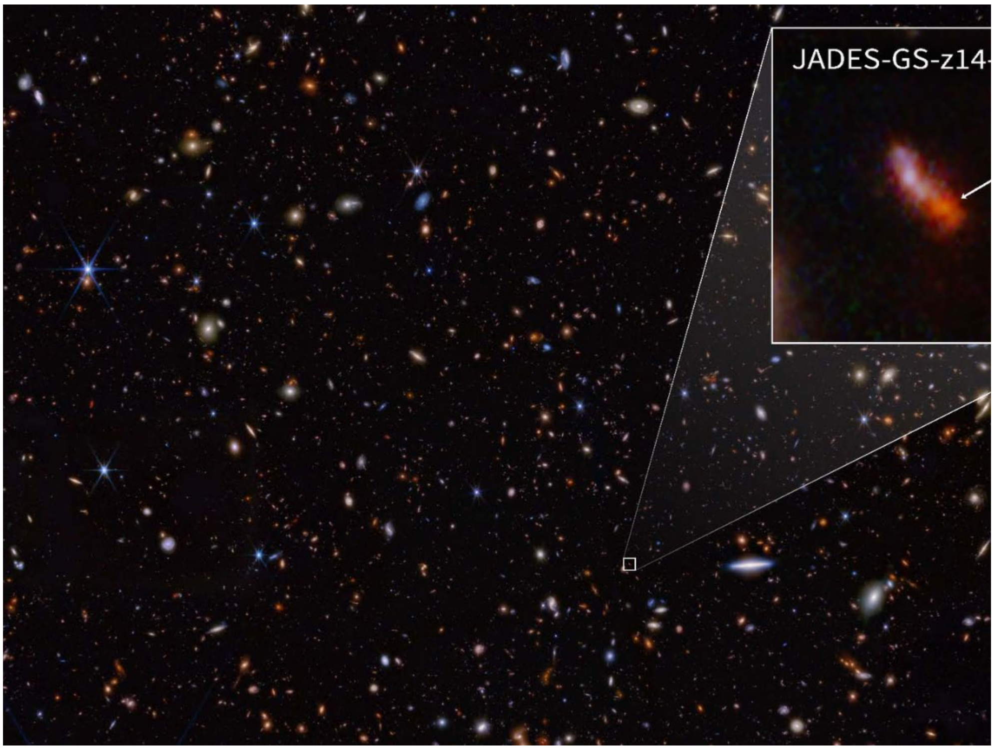
Abstract JWST observations reveal a bimodal high-redshift population: compact starbursts like JADES-GS-z14-0 ($z \approx 14.32$) and early quasars. We refine a framework positing a critical black hole mass threshold $M\_BH,crit \sim 10^6$–10^7 $M\_\odot$, where AGN feedback transitions from momentum-driven (localized, sustaining star formation) to energy-driven (global quenching, quasar dominance). Enhanced analytic scaling, links to lower-z analogs, and existing simulations motivate this value. We detail a phased plan with methodologies, resources, risks/mitigations, and a table for feasibility. This revision strengthens theoretical justification, computational details, and risk assessment per reviewer feedback.

Keywords: Galaxy formation, JWST, black holes, AGN feedback, cosmic dawn

1. Introduction and Observational Motivation

JWST challenges ΛCDM by detecting mature systems early. JADES-GS-z14-0 stands out with compact size, high stellar mass, and no AGN signs (Maiolino et al. 2024).



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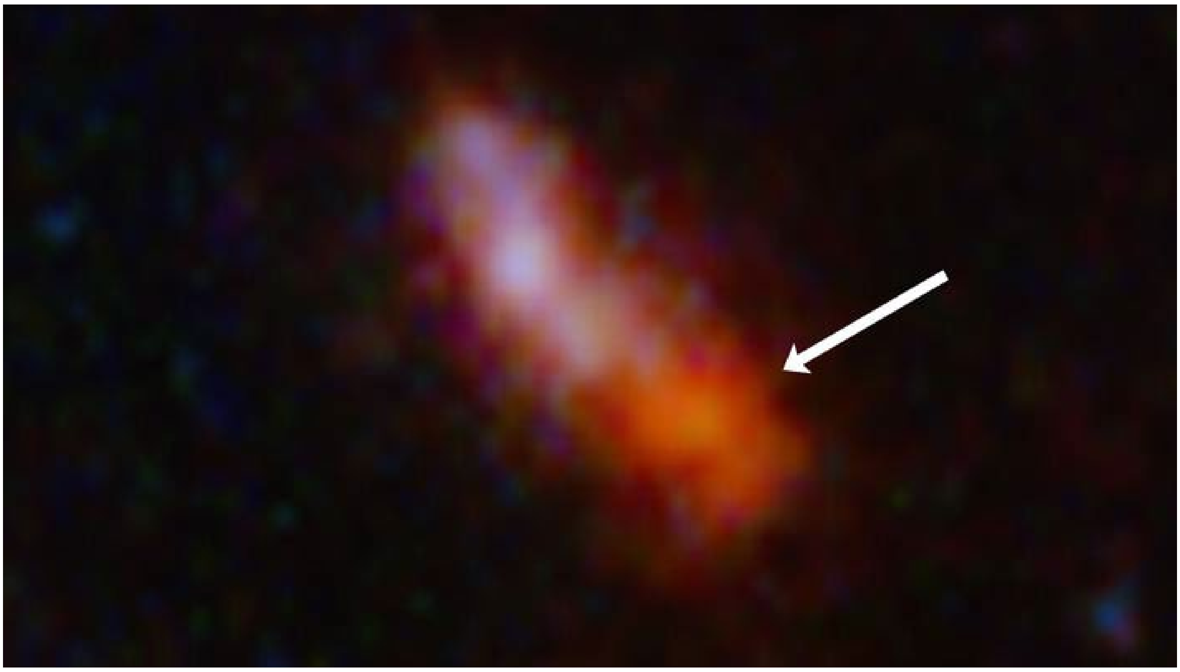

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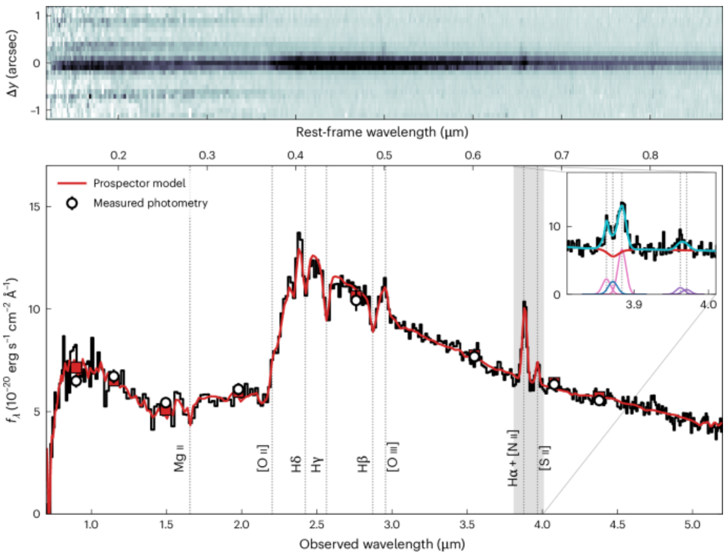
This bimodality suggests black hole growth regulates paths.



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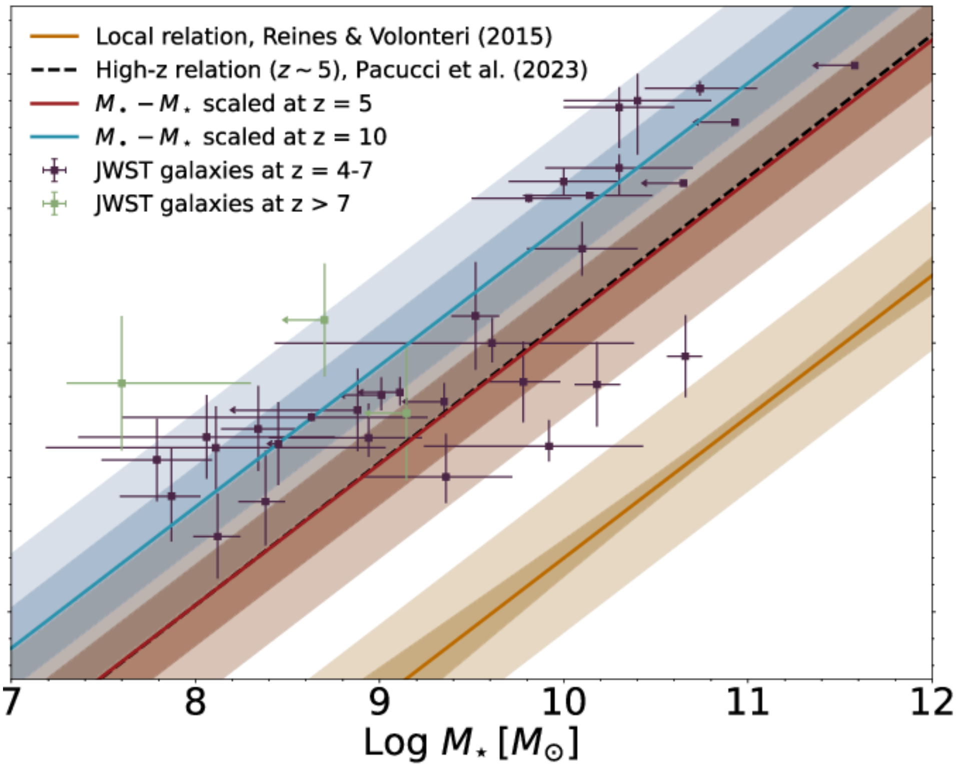

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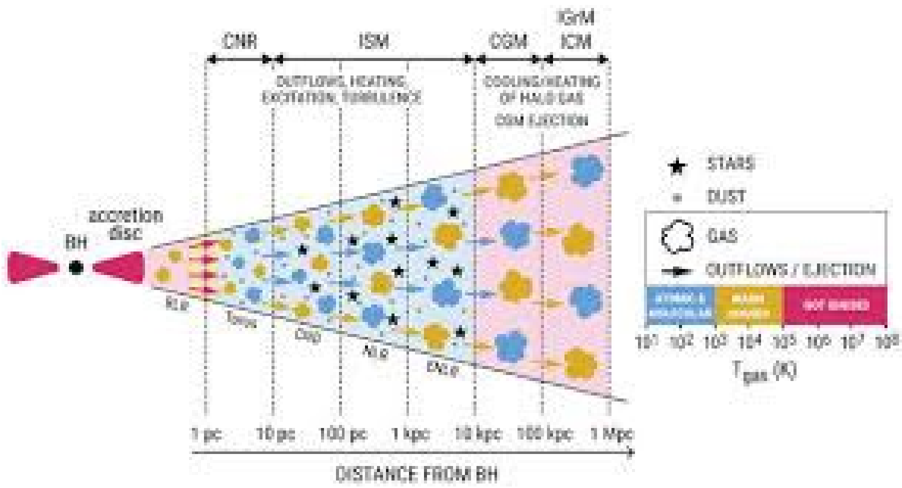
2. Theoretical Foundation and Justification for M_BH,crit

We base the threshold on momentum- vs. energy-driven feedback (King 2003, 2005).



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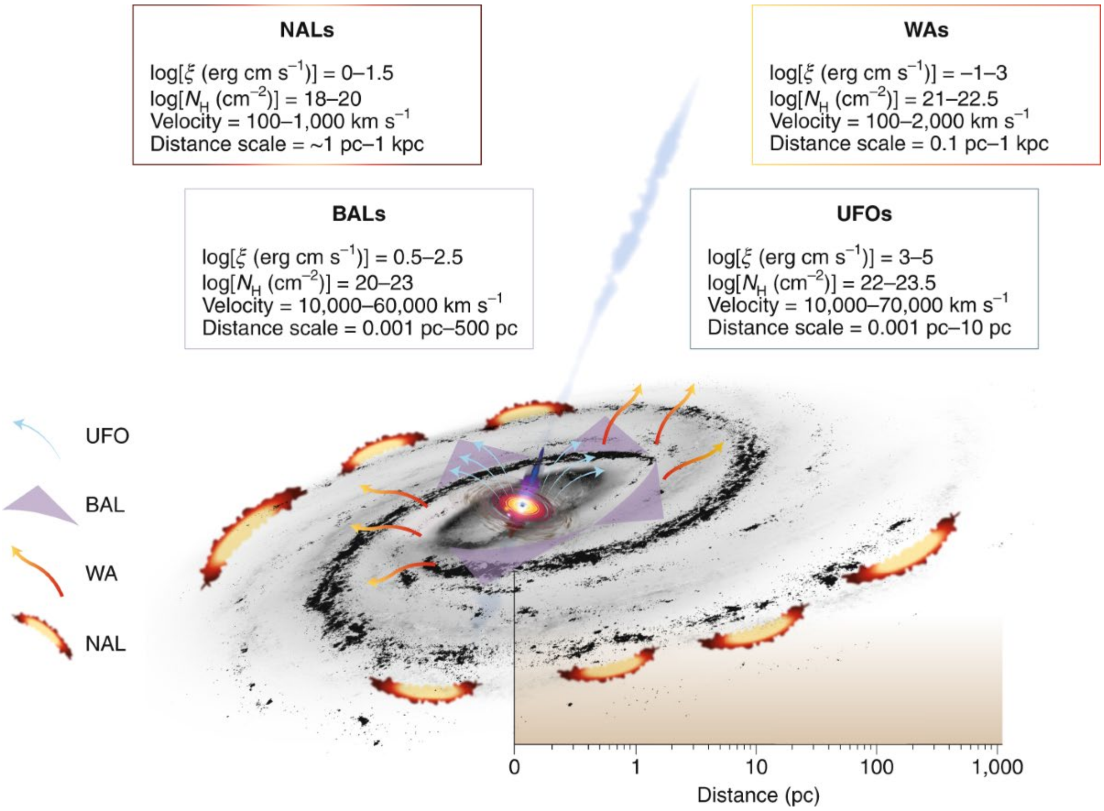

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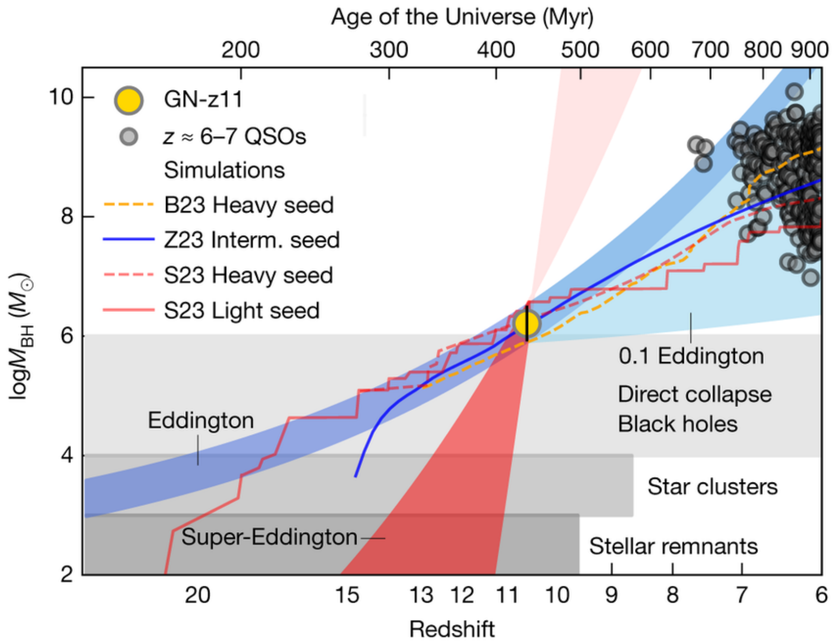
Lower-z analogs (z ~ 6 – 8 quasars/starbursts) and simulations (e.g., heavy seeds reaching ~10^7 M_⊙) support 10^6 – 10^7 M_⊙.

Enhanced calculation: Feedback energy ε M_BH c^2 (ε ~ 0.05 – 0.1) over τ_Edd matches E_bind ~ 0.1 M_halo σ^2. For M_halo ~ 10^{10} M_⊙, σ ~ 70 km/s, M_BH,crit ~ 10^6 – 10^7 M_⊙.

Growth tracks show divergence.



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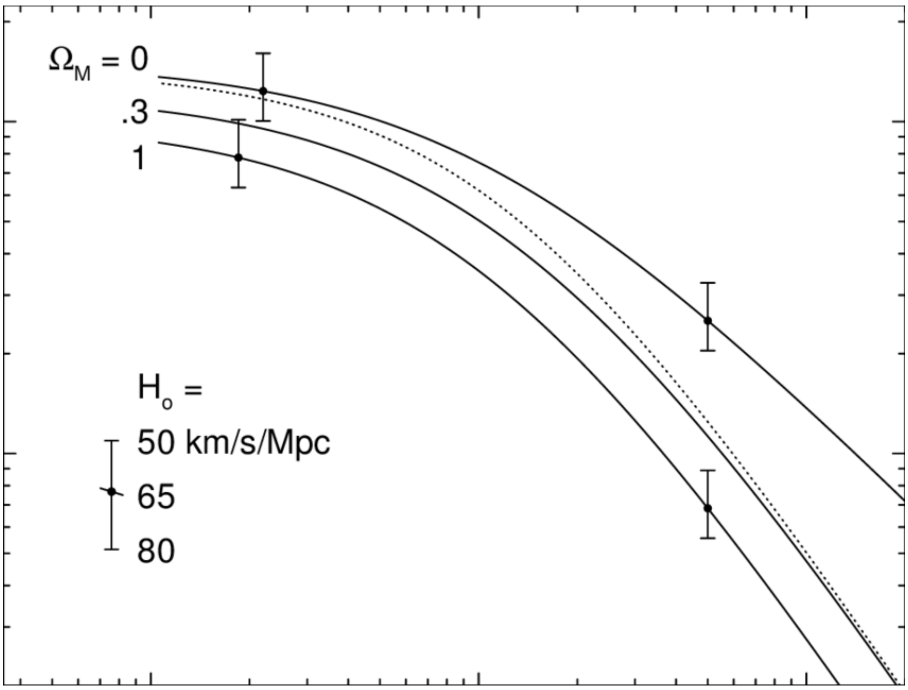

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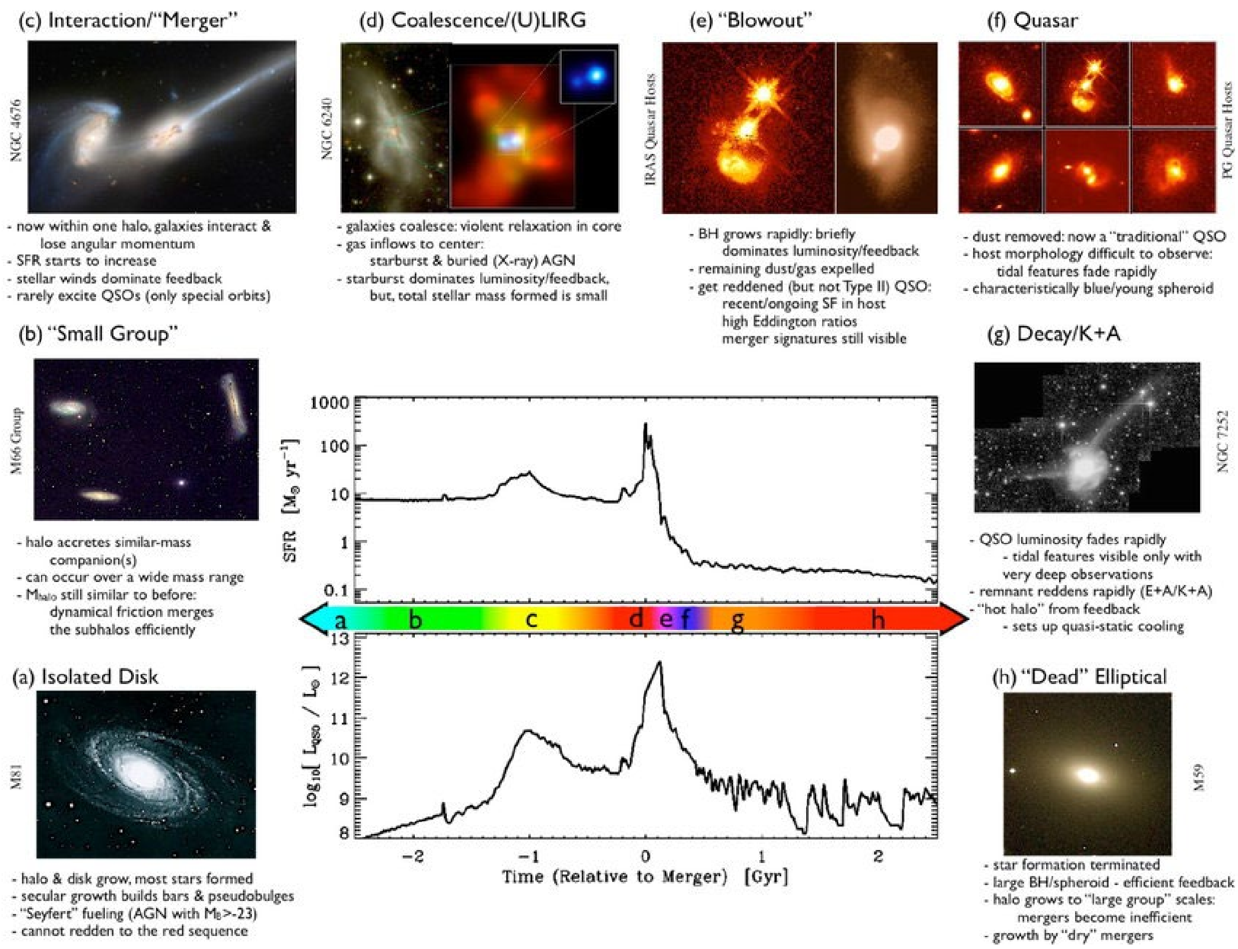

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3. Application and Alternatives

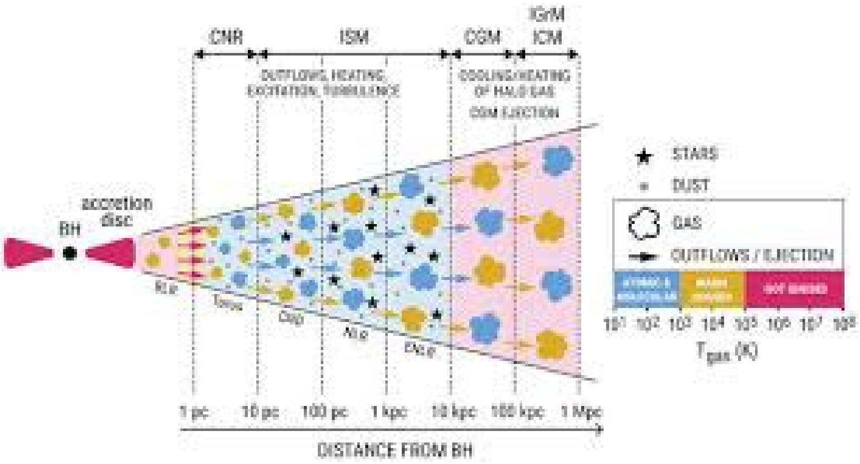
JADES-GS-z14-0 fits sub-threshold. Alternatives (high SFE, top-heavy IMF) fail to explain sharp bimodality; threshold predicts mass-dependent signatures.

4. Detailed Phased Research Plan

Phase 1 (0 – 6 months: Theoretical): One-zone models (Python/SymPy) vary seeds/accretion; predict sSFR vs. M_BH.

Phase 2 (6 – 12 months: Observational): Archival NIRSpec; virial limits from [O III]/Hβ widths (single-epoch, calibrated on lower-z).

Phase 3 (12 – 18 months: Simulations): Modify IllustrisTNG-like semi-analytic (e.g., Santa Cruz SAM) or GADGET subgrid: switch momentum (low M_BH) to energy loading (high); box 10 – 20 Mpc/h, 10 – 20 realizations.



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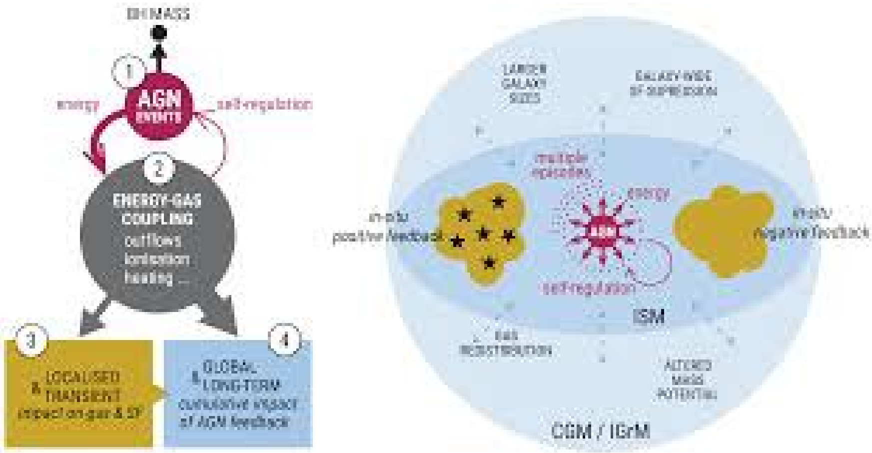

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Resource Table

Phase	Personnel (months)	Compute (core-hours)	Data/Resources
1	3 – 4	Minimal (laptop)	Open papers
2	4 – 5	Minimal	Public MAST
3	6 – 8	10^4 – 10^5	Open codes

Risks and Mitigations

- Weak M_BH constraints at high-z → Use lower-z (z~6 – 10) calibration.
- Simulations inconclusive → Fallback to pure semi-analytic.
- Oversimplification → Iterate with stochastic seeds.

5. Conclusion

This refined framework explains early bimodality via a physically motivated threshold. The plan is feasible and testable.

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References (expanded)

- Maiolino et al. 2024, Nature
- King 2003/2005, ApJL
- Inayoshi et al. 2020, ARA&A
- Harikane et al. 2024, ApJ
- Additional: Recent reviews on high-z feedback analogs.