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Physical Pathways for JWST-Observed Supermassive Black Holes in the Early Universe

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Observations with the James Webb Space Telescope (JWST) have revealed active galactic nuclei (AGN) powered by supermassive black holes with estimated masses of 10^7–10^8 M⊠ at redshifts z~7–9. Some reside in overmassive systems with higher AGN to stellar mass ratios than locally. Understanding how massive black holes could form so early in cosmic history and affect their environment to establish the observed relations today are some of the major open questions in astrophysics and cosmology. One model to create these massive objects is through direct collapse black holes (DCBHs) that provide massive seeds (~10^5–10^6 M⊠), able to reach high masses in the limited time available. We use the cosmological simulation code GIZMO to study the formation and growth of DCBH seeds in the early Universe. To grow the DCBHs, we implement a gas swallowing model that is set to match the Eddington accretion rate as long as the nearby gaseous environment, affected by stellar and accretion disk feedback, provides sufficient fuel. We find that to create massive AGN in overmassive systems at high redshifts, massive seeds accreting more efficiently than the fiducial Bondi-Hoyle model are needed. We assess whether the conditions for such enhanced accretion rates are realistic by considering limits on plausible transport mechanisms. We also examine various DCBH growth histories and find that mass growth is more sustained in overdense cosmological environments, where high gas densities are achieved locally. We discuss the exciting prospect to directly probe the assembly history of the first SMBHs with upcoming, ultra-deep JWST surveys.

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