Mass accretion by black holes (BHs) is typically capped at the Eddington rate, when radiation’s push balances gravity’s pull. However, even exponential growth at the Eddington-limited e-folding time $t_E \sim \text{few} \ast 0.01$ billion years is too slow to grow stellar-mass BH seeds into the supermassive luminous quasars that are observed when the universe is 1 billion years old. We propose a dynamical mechanism that can trigger supra-exponential accretion in the early universe, when a BH seed is bound in a star cluster fed by the ubiquitous dense cold gas flows. The high gas opacity traps the accretion radiation, while the low-mass BH’s random motions suppress the formation of a slowly draining accretion disk. Supra-exponential growth can thus explain the puzzling emergence of supermassive BHs that power luminous quasars so soon after the Big Bang.