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Pathway to high-z SMBHs: seed formation and growth in the statistical perspective

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The early evolution of the black hole mass function (BHMF) and quasar luminosity function (QLF) encodes key information on the physics determining the radiative and accretion processes of black holes (BHs) growing in high-redshift galaxies. Starting from the formation of seed BHs as their parent halos evolve, we study primordial gas collapse in the biased quasar host halos, computing gas chemical and thermal evolution, environmental UV radiation, and merger heating following halo merger trees. As gas collapses, the accretion rate onto a newly-born protostar ranges between 0.003-5 Msun/yr, leading to a top-heavy seed BH mass distribution ranging from several hundred to above 10^5 solar mass. We then construct a theoretical BH growth model via multiple accretion bursts constrained by z~6 QLF and BHMF observations. In a statistical way, we predict that in every active episode, BHs grow with an Eddington ratio distribution function following the Schechter shape. Imposing a luminosity limit of quasar surveys, we find that the observed Eddington-ratio distribution function is skewed to a log-normal shape, preferentially selecting more active quasars. The predicted redshift evolution of the QLF and BHMF suggests a rapid decay of their number and mass density in a cosmic volume toward z>6. JWST and future devices will push BH observations to mass ranges lower than typical high-redshift quasars, and help explore the growth history of BHs in the early universe and the establishment of BH-galaxy coevolution.

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