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A Lower Limit on the Halo Mass to form Supermassive Black Holes

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We consider a scenario where supermassive black holes form through direct accumulation of gas at the centre of proto-galaxies. In the first stage, the accumulated gas forms a super-massive star whose core collapses when the nuclear fuel is exhausted, forming a black hole of $M_{\rm BH} \approx 100 M_{\sun}$. As the black hole starts accreting, it inflates the surrounding dense gas into an almost hydrostatic self-gravitating envelope, with at least 10-100 times the mass of the hole. We find that these "quasistars" suffer extremely high rates of mass loss through winds from their envelopes, in analogy to very massive stars such as eta-Carinae. Only for envelope masses greater than 2.8 \times 10^{5} (M_{\rm BH}/100 M_{\sun})^{9/11} is the envelope evaporation time-scale longer than the accretion time-scale of the black hole. This relation thus constitutes a "threshold growth line" above which quasistars can grow their internal black holes. Accretion rates can be 10 to 100 times the Eddington rate. The quasistars born in this "growth region" with 10^7-10^8 M_{\sun} can grow black holes with masses between 10^4$ to $10^5 M_{\sun}, before crossing the threshold growth line and dispersing their envelopes in less than 10^4 yr. This scenario therefore predicts that massive black hole seeds can be found only in dark matter halos with total masses larger than about 10^9 M_{\sun}, which can provide sufficiently high accretion rates to form such massive quasistars.

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