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Quantifying the Coupling Effects of Supernova Feedback on Black Hole Accretion in Galactic Nuclei

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Growth of massive black holes (BHs) in the galactic centers are regulated by the environment. Modern cosmological galaxy-formation simulations suggest that supernova (SN) feedback evacuates the gas in galactic center, suppressing the BH growth until the host galaxies have grown sufficiently to develop a deep gravitational potential, leading to under-massive growth track relative to the local relationship. However, this scenario does not explain the over-massive nature of BHs observed at high redshift through JWST. In this work, we perform a suite of 3D high-resolution hydrodynamical simulations that investigate the properties of turbulent, multi-phase gas driven by individual SN explosions, and the dynamics of accreting gas onto a BH through its gravitational influence radius. We explore a broad parameter space of the BH mass (~ 10^4 - 10^7 Msun), density of the surrounding gas (~ 1-10^5 cm^-3), and frequency of explosions (given by star-formation timescale, tau ~ 10-10^4 Myr). When the density in the nucleus is as high as > 10^3 cm^-3 (tau / 10^2 Myr)^(-2), where the volume filling factor of SN bubbles within the BH influence radius is less than 0.1, the BH is fed at a high rate comparable to the Bondi accretion rate by dense cold gas formed between SN bubbles. This result, unlike most large-scale galaxy simulations that hardly resolve the nucleus, suggests that SN feedback is inefficient to expel the gas and prevent the BH from growing. These high-resolution simulations enable us to provide a physically motivated subgrid feedback model, which can be applied to large-scale simulations.

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