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Tracing Cosmic Evolution through Dark Matter Phenomena: Insights from Primordial Black Holes and Supermassive Dark Stars

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The James Webb Space Telescope (JWST) has dramatically advanced our understanding of cosmic history, revealing new aspects of dark matter (DM) phenomena, particularly through our studies on Primordial Black Holes (PBHs) and Supermassive Dark Stars (SMDSs). These studies enhance our knowledge of the dark sector's role in the early universe and serve as an indirect probe for DM.

Our research utilizes N-body simulations with the GIZMO code and semi-analytical models to investigate PBHs' impact. We find that stellar-mass PBHs, ranging from 10-100 $M_\odot$ and constituting a fraction of 10^{-4} to 0.1 of DM, subtly influence the formation of the universe's first stars by maintaining the standard model of star formation, while their accretion feedback shifts star formation to more massive halos. Additionally, PBHs significantly contribute to the cosmic radiation background during reionization and might facilitate the formation of direct-collapse black holes. On the other hand, more massive PBHs with $10^6 M_\odot$, could seed massive halos and disrupt hierarchical structure formation by engulfing newly formed halos.

Conversely, SMDSs, powered by DM and primarily consisting of hydrogen and helium, form at redshifts around $z \sim 10 - 20$. Using the Roman Space Telescope (RST), we could detect SMDSs up to $z \simeq 14$. The distinction between SMDSs and early metal-free galaxies relies on spectral, photometric, and morphological analyses, with the HeII λ1640 absorption line serving as a smoking gun. Identification of SMDS candidates by the RST photometry, complemented by JWST spectroscopy, could confirm the existence of a novel star class and illuminate the origins of supermassive black holes underlying ancient quasars.

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