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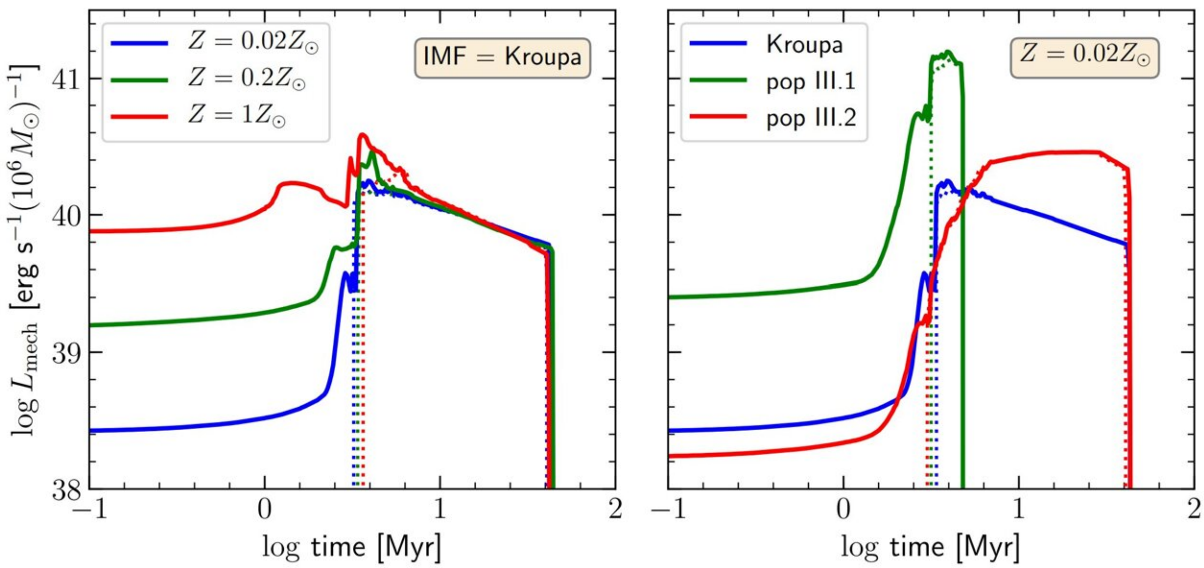
# New theoretical model claims to solve mystery of early massive galaxies

May 31 2023




Feedback mechanical energy injection rate as computed by Starburst99 for an instantaneous starburst in a star cluster of 106? as a function of time from the burst. Shown are curves for different metallicities and different IMFs. For each case, the solid curve refers to the total energy of stellar wind and supernova and the dotted curve is the contribution of supernovae only. Left: Three different metallicities for a standard Kroupa IMF. Right: Three different IMFs at a low metallicity ? =0.02?. Robustly in all cases, the onset of supernova feedback is sharp at ? '3 Myr when it becomes dominant. Except for ? =1?, the early stellar-wind feedback is negligible until it rises steeply near ? '2 Myr. Thus, at sufficiently low metallicity, a burst of ∼1 Myr is expected to be safely free of both stellar-wind feedback and supernova feedback. Credit: *Monthly Notices of the Royal Astronomical Society* (2023). DOI: 10.1093/mnras/stad1557

Astrophysicists from the Hebrew University of Jerusalem published a new theoretical model that solves the mystery of the formation of early massive galaxies in the universe, in *Monthly Notices of the Royal Astronomical Society*. The findings naturally explain recent observations conducted using the James Webb Space Telescope (JWST), which revealed a surprising excess of massive galaxies in the universe—already in the first half billion years after the Big Bang—contrary to the commonly accepted theory.

The James Webb telescope was launched into space at the end of 2021 and started producing images of distant galaxies as early as July 2022. Researchers unexpectedly discovered an excess of massive galaxies in the early universe compared to the number of galaxies expected according to the common theory.

According to the researchers' proposed model, the special conditions that prevailed in the primordial galaxies, of high density and low abundance of heavy elements, allowed the formation of stars with high efficiency without interference from other stars. The research team from the Racah Institute of Physics at the Hebrew University, was led by Professor Avishai Dekel with Dr. Kartick Sarkar, Professor Yuval Birnboim, Dr. Nir Mandelker, and Dr. Zhaozhou Li.

"Already in the first half-billion years, researchers identified galaxies that each contain about ten billion stars like our sun," shares Professor Dekel. "This discovery surprised researchers who tried to identify plausible explanations for the puzzle, ranging from the possibility that the observational estimate of the number of stars in galaxies is exaggerated, to suggesting the need for critical changes in the standard cosmological model of the Big Bang."

According to the prevailing theory of galaxy formation, gravity causes gas scattered in the universe to collapse into the centers of giant spherical clouds of dark matter, where it becomes luminous stars, like the sun. However, theory and observations to date have shown that the efficiency of star formation in galaxies is low, with only about 10 percent of the gas that falls into the clouds becoming stars.

The inefficiency is caused by remaining gas heating up or being blown out of galaxies under the influence of winds and supernova explosions from the stars that manage to form first. This contradicts recent JWST indications of vast amounts of stars created in a short time frame.

In this study, Professor Dekel and his team propose a process termed "feedback-free starburst" (FFB), which naturally explains the mystery. Under the unique conditions prevalent in early galaxies, gas efficiently turns into stars without being disrupted by feedback processes. This idea is based on a time delay of more than one million years between the formation of massive stars and their subsequent explosions as supernovae.

Prior to the enrichment of the gas by heavy elements produced in stars, the researchers suggest star-forming clouds in the dense early universe had a density above a threshold that allowed rapid collapse of the gas into stars within the "window of opportunity" of one million years. This process of high-efficiency star formation in the absence of feedback explains the observed excess of massive galaxies.

"The publication of this research marks an important step forward in our understanding of the formation of primordial massive galaxies in the universe and will no doubt spark further research and discovery," concludes Professor Dekel. "The predictions of this model will be tested using the accumulating new observations from the Web Space Telescope, where it seems that some of these predictions are already confirmed."

Dekel adds that important implications of the proposed FFB scenario will be investigated in future studies. These include the efficient formation of seed black holes of a thousand solar masses in the centers of the FFB star-forming clusters, which are a key to explaining the surprisingly super-massive black holes of a billion solar masses seen in centers of galaxies half a billion years later.

**More information:** Avishai Dekel et al, Efficient formation of massive galaxies at cosmic dawn by feedback-free starbursts, *Monthly Notices of the Royal Astronomical Society* (2023). DOI: 10.1093/mnras/stad1557

Provided by Hebrew University of Jerusalem

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