Cosmological significance of the early bright galaxies observed with JWST

Moncy Vilavinal John*, K. Babu Joseph†

* School of Pure and Applied Physics, Mahatma Gandhi University, Kottayam, India, † Department of Physics, Cochin University of Science and Technology, Kochi, India

Unexpected early bright galaxies

The near infra-red camera (NIRCam) imaging data from the Glass-JWST Early Release Science Program (JWST-ERS-1324) helped to identify several massive and bright galaxy candidates in the cosmic dawn. Two particularly luminous sources GL-z10 and GL-z12 were identified by Naidu et.al. at high redshifts $z = 10.4^{+0.4}_{-0.5}$ and $z = 12.4^{+0.1}_{-0.3}$.

Ref: Naidu, R.P. et al.: Two remarkably luminous galaxy candidates at $z \approx 10$-12 revealed by JWST. The Astrophysical Journal Letters, **940**, L14 (2022)

Castellano et. al. measured these objects to be at $z = 10.6$ and $z = 12.2$, respectively. These objects appear to be over a million solar masses and might have built-up their masses in only $t < 300 - 400$ Myr after the Big Bang.

Ref: Castellano, M. et al.: Early results from GLASS-JWST. III. Galaxy candidates at $z \sim 9 - 15$. The Astrophysical Journal Letters, **938**, L15 (2022)

As per the accounts of the cold dark matter (CDM) cosmology, galaxies were formed only at around redshift $z \sim 5$. The currently popular ΛCDM cosmology pushes this limit to $z \sim 6 - 9$.

It is noted that even in this case, the above two high redshift objects with $z > 10$ are quite unexpected in the small survey volume of the observation.

Another recent paper reports six other candidate massive galaxies at $7.4 \leq z \leq 9.1$, which are estimated to be within 500-700 Myrs after the Big Bang in the ΛCDM model.

Ref: Labbe, I. et al.: A population of red candidate massive galaxies ~ 600 Myr after the Big Bang. Nature **616**, 266-269 (2023)

The mass in these galaxy candidates would be a factor of $\approx 20 - 1000$ higher than the expected values, and the mass density in the most massive galaxies would exceed the total previously estimated mass density by a factor of 2-5.

It is observed that these stellar mass densities are difficult to realize at these redshifts in the standard ΛCDM cosmology.

Recent discovery of the two companion sources to a strongly lensed galaxy SPT0418-47 at $z = 4.225$ is claimed to be a good example of the very early mass build-up and structure formation.

This object possesses extra-ordinarily high (solar-like) metallicity at the age of 1.4 Gyr in the ΛCDM model, which appears to be in tension with the theories of galaxy formation.

Ref: Peng, B. et al.: Discovery of a dusty, chemically mature companion to a $z \sim 4$ starburst galaxy in JWST ERS data. The Astrophysical Journal Letters, **944**, L36 (2023)

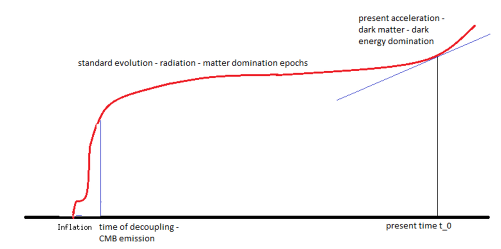
Attempts to resolve the tension

It is widely believed that the new data can be reconciled only through a significant transition in the mode of galaxy formation in the early universe.

We find it equally important to look for possible alternatives to the cosmic evolution itself at least in the early epochs.

Eternal coasting universe

We consider an alternative cosmological model that can offer potential solution to this impasse by way of having an evolution different from that of the ΛCDM model. This model is referred to as 'eternal coasting', for in it the scale factor of the universe always varies linearly with time ($a \propto t$).



This model was proposed on the basis of some dimensional considerations, which led to the conclusion that densities of all matter/energy components in the classical universe must vary as the inverse square of the scale factor. In consequence, the total energy density obeys $\rho + 3p = 0$. Here, the active gravitational mass of the universe must be zero throughout its evolution, starting from a singularity.

The cosmic fluid was assumed to contain visible and dark matter with density ρ_m and an equation of state $p_m = w\rho_m$ ($w = 1/3$ for radiation and $w = 0$ for nonrelativistic matter), and also a time-varying dark energy $\rho_\Lambda(t)$ with equation of state $p_\Lambda = -\rho_\Lambda$.

The time evolution of the scale factor is coasting, given by

$$a = mt, \qquad (1)$$

where $m = \sqrt{k/(\tilde{\Omega} - 1)}$ is a proportionality constant; $\tilde{\Omega}$ is the total density parameter. With Ω_m as the density parameter for matter and Ω_Λ that for dark energy, we have $\tilde{\Omega} = \Omega_m + \Omega_\Lambda$.

In addition to the absence of horizon, flatness and other related cosmological problems, the eternal coasting model has the advantage that it does not have the coincidence problem in cosmology.

A feature unique to the eternal coasting model is that the density parameters such as Ω_m and Ω_Λ are constants in time. A clearly falsifiable prediction of the model is that the ratio between densities of matter and dark energy is 2.

For all cases (closed, open or flat) of the eternal coasting model, the age of the universe at $z = 12$ can be seen to be ~ 1.07 Gyr, given the present value of Hubble parameter as 70 km s^{-1} Mpc^{-1}. Even for larger values of z, the age of the universe is substantial; for $z = 20$, it is ~ 700 Myr. The redshift corresponding to an age 500 Myr can be seen to be $z = 27$.

These values show that it would not be surprising if galaxies with redshifts up to such large values of z are detected in future observations. The new early bright galaxy candidates observed with JWST do not create any problem in this model.

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