Updates

Update #1

"*ΛCDM not dead yet: massive high-z Balmer break galaxies are less common than previously reported*" [1]

As I explained in my thesis, recent results from the James Webb Space Telescope have challenged the ΛCDM cosmological model. For example, the existence of several massive high-redshift galaxy candidates in the Cosmic Evolution Early Release Science Survey (CEERS) was reported in [2] (hereafter L22). The candidates were chosen on the basis of a double-break feature in their photometric spectral energy distributions (SEDs), which are attributed to Lyman and Balmer breaks redshifted to $z > 7$. It was immediately pointed out that, within reasonable stellar formation efficiencies (SFEs), the data disagreed with the standard cosmological model [3]. In the article [1], the authors look for double-break sources similar to those in L22, to better understand the disagreement. They use the Canadian NIRISS Unbiased Cluster Survey (CANUCS), imaging over 10 fields along 5 separated lines-of-sight, for a total area of 100 arcmin^2, allowing for control of cosmic and sample variances. In all 10 fields, galaxies are looked for with the same photometry criteria as in L22. Then, for all sources, redshifts are estimated either with spectroscopy when available or fitted with 2 different codes, `Phosphorus+DB` and `Bagpipes`. The redshift fit is also done for the candidates in L22, to ensure that they can be compared to the new results. Then, the photometry for each source is fit to measure its stellar mass. The entire sample consists of 19 double break galaxies, five of which were observed with spectroscopy, and all the other ones were fitted to find their redshifts.

The results are that, first of all, the CANUCS double break population remains under the mass threshold of $10^{10} M_\odot$, regardless of the code used for the fits. Furthermore, the authors calculate the comoving stellar mass density, focusing on redshifts $z \sim 8$, comparable to L22's $z \sim 7-8.5$ range. They find that the `Phosphorus+DB` fit results for the CEERS sample are consistent with the results in L22, and a good agreement between the two fitting codes. However, the major outcome is that the CEERS and CANUCS samples provide different density distributions, the CEERS one lying above ΛCDM predictions, while the CANUCS one below it. The following figure shows the various discrepancies:

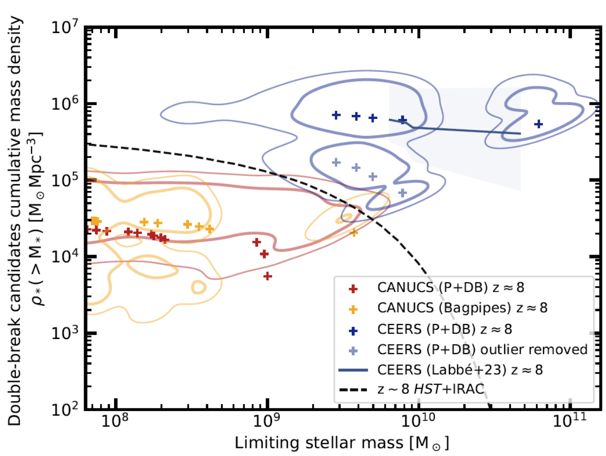

Figure 1: Comoving cumulative stellar mass densities of the double-break candidates in the range $z = 7{-}8.5$ for both CEERS and CANUCS (for both codes). The prediction based on ΛCDM (HST+IRAC) is also shown. The contours represent the 1 (thick)- and 2(thin)-σ errors.

Therefore, despite using candidates with the same SEDs properties, the authors find no tension with cosmological predictions based on ΛCDM. The reasons could be due to mainly 4 factors:

- Emission lines rather than Balmer breaks: it happens to be the case that for some candidates the red break can indeed be a Balmer break due to evolved stellar populations, but for some, strong optical emission lines can be mistaken as a break in their photometry, leading to a wrong (and higher) deduced stellar mass. To break this degeneracy, spectroscopy is in general needed. Indeed, for the 5 sources that were analysed with NIRSpec, no Balmer breaks were visible. Clearly, the whole sample is not to be ruled out just because of these 5 sources, however, this at least indicates that emission lines, rather than Balmer breaks, are a more plausible cause of the photometric breaks. Further spectroscopic results are needed.

- Getting the right redshift: the mass fit of the sources depends very sensitively on their redshift. This underlines the importance of obtaining proper redshifts from spectroscopy, since, as is noted here below, the whole sample might be highly influenced by an outlier.

- Field-to-field variance: the authors highlight how the higher mass density from CEERS is likely to be mostly due to cosmic variance, despite L22 estimating its effect to be only 30%. The problem is that L22 only used one line-of-sight (contrary to CANUCS, where five were used), making the results highly susceptible to sample bias.

- Effect of outliers: as can be seen in Figure 1, the comoving stellar mass density depends strongly on the most massive object in the sample. The authors illustrate also how the CEERS sample would be consistent with the cosmological predictions, if the outlier is disregarded (the light blue curve in the Figure). This shows the problem with small samples such as the L22 one. Even assuming that all candidates are real double-break galaxies, the size of the sample and the volume which is probed is far too limited to allow for generalisations.

In the future, deep spectroscopy over large areas and over different sight-lines will be needed to effectively understand the conclusions drawn in L22.

References

[1] G. Desprez *et al.*, "ΛCDM not dead yet: massive high-z Balmer break galaxies are less common than previously reported," Oct 2023.

[2] I. Labbé *et al.*, "A population of red candidate massive galaxies ∼600 Myr after the Big Bang," *Nature*, vol. 616, pp. 266–269, Feb 2023.

[3] M. Boylan-Kolchin, "Stress testing ΛCDM with high-redshift galaxy candidates," *Nature Astronomy*, vol. 7, pp. 731–735, Apr 2023.