Analyzing High-Redshift Galaxy Candidates as Supermassive Dark Star Candidates with JWST Data

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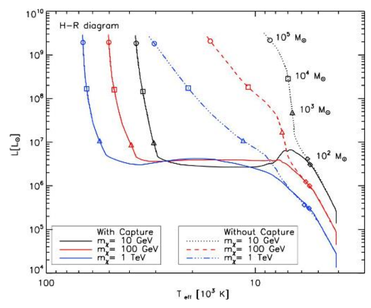
Introduction

- Problem: too many galaxies, too early in the universe
- What if some of these galaxies were Dark Stars?
- Dark Stars (DS) [1, 2]:
  - Theoretical; form in dark matter (DM) haloes
  - Form via Extended Adiabatic Contraction (AC) or with DM capture
  - Powered predominantly by DM annihilations rather than fusion



Selection of Candidates & Method

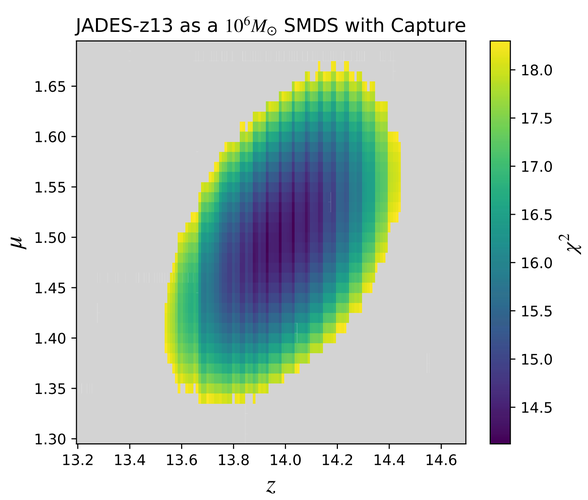
- Unresolved (resolution limit of JWST ~0.1'')
- Spectroscopically confirmed Lyman break
- Good fits (data from [3, 4]):
  - JADES-GS-z13-0 (SMDS with Capture)
  - JADES-GS-z12-0 (SMDS with AC)
  - JADES-GS-z11-0 (SMDS with AC)
- Photometric fit using χ^2 analysis
- Take average flux in each NIRCAM photometric band:

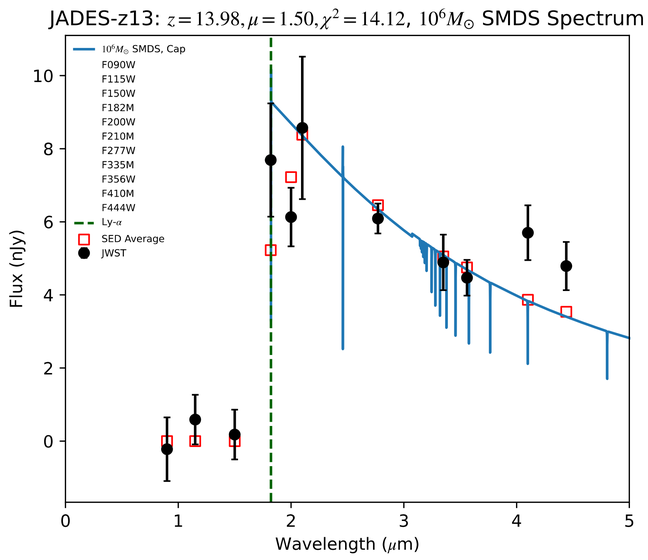
$$\tilde{F}_{\nu;b}(M_\star; z_{emi}) = \frac{\int_{\lambda_{min}}^{\lambda_{max}} T(\lambda_{obs}) F_\nu(\lambda_{obs}; M_\star; z_{emi}) \frac{d\lambda_{obs}}{\lambda_{obs}}}{\int_{\lambda_{min}}^{\lambda_{max}} T(\lambda_{obs}) \frac{d\lambda_{obs}}{\lambda_{obs}}}$$

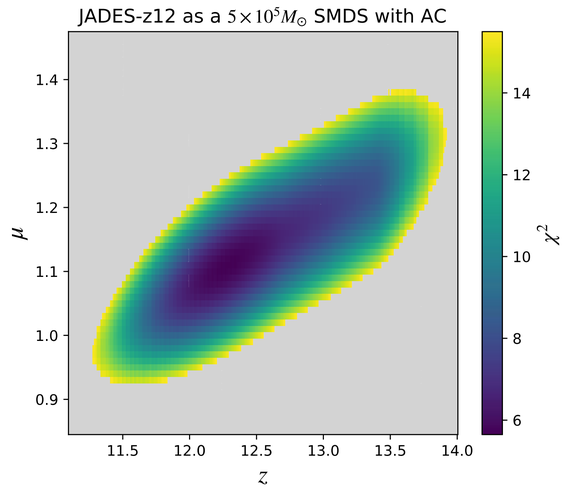
- Calculate χ^2 by the following:

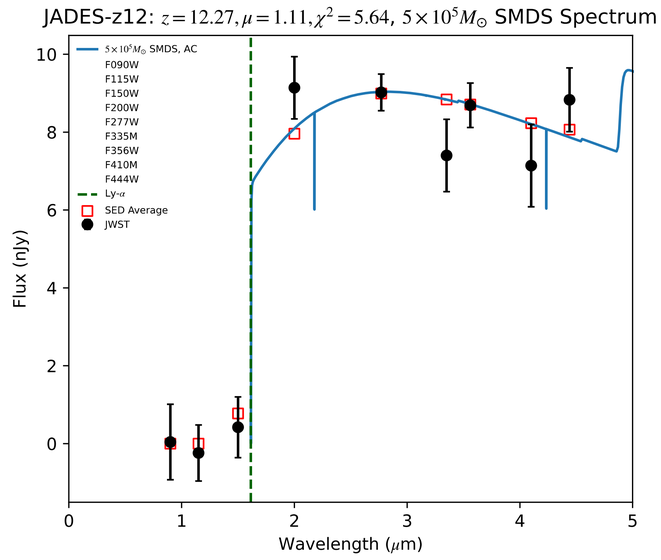
$$\chi^2 = \sum_b \frac{(f_{\nu;b} - \mu \times \tilde{F}_{\nu;b}(M_\star; z_{emi})^2}{\sigma^2(f_{\nu;b}) + \sigma^2_{sys}(b)}$$

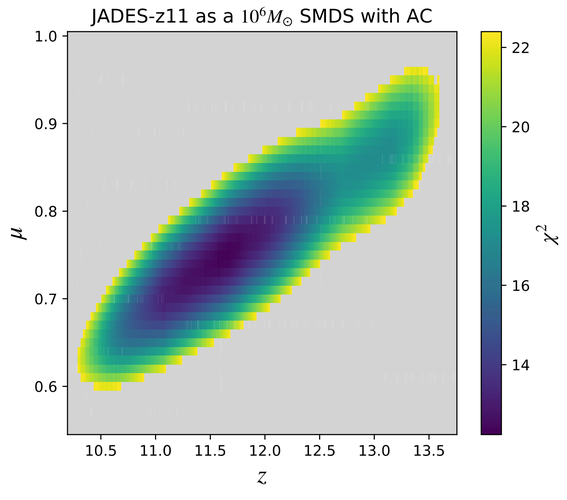
Results

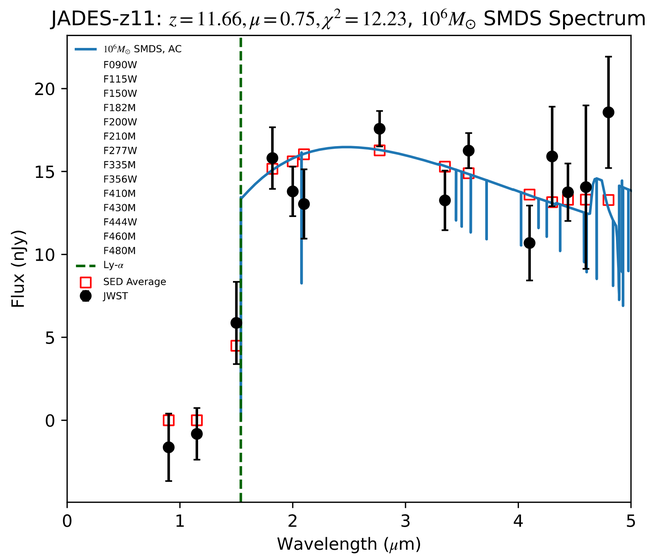












Discussion

- There is a degeneracy between μ and M for SMDS with capture
- In [3], the authors claim that JADES-z11 and JADES-z12 are resolved; they are actually unresolved (resolution limit of JWST is ~0.1'')
- Notice: μ<1 for our JADES-GS-z11-0 fit
  - De-lensing is possible at very high redshift [5]
- Follow-up spectroscopy is required to distinguish SMDS from galaxies

References

[1] D. Spolyar, K. Freese, and P. Gondolo, Dark matter and the first stars: a new phase of stellar evolution, Phys. Rev. Lett. **100**, 051101 (2008), arXiv:0705.0521

[2] K. Freese, C. Ilie, D. Spolyar, M. Valluri, and P. Bodenheimer, Supermassive Dark Stars: Detectable in JWST, Astrophys. J. **716**, 1397 (2010), arXiv:1002.2233

[3] B.E. Robertson et al, Discovery and properties of the earliest galaxies with confirmed distances, arXiv e-prints, arXiv:2212.04480 (2022)

[4] E. Curtis-Lake et al, Spectroscopic confirmation of four metal-poor galaxies at z=10.3-13.2, arXiv e-prints, arXiv:2212.04568 (2022)

[5] Y. Wang, D.E. Holz, and D. Munshi, A Universal Probability Distribution Function for Weak-lensing Amplification, Astrophys. J. **572** (2002)