To Stack or Not to Stack:
Lessons from $z=2.1$ Ly$\alpha$ Emitting Galaxies

Carlos J. Vargas$^{1,2}$
Hannah Bish$^2$, Eric Gawiser$^2$, Viviana Acquaviva$^{2,3}$, Steve Finkelstein$^4$, and the CANDELS Team

(1) New Mexico State University; (2) Rutgers, The State University of New Jersey; (3) CUNY NYC College of Technology; (4) University of Texas at Austin

The Significance of Lyα Emitters (LAEs)

- Strong Lyα emission – detectable at high redshift
- Narrowband filter discovery
- Progenitors of Milky Way-type galaxies
How Do We Find LAEs?

• Signal to noise ratios of a source in a narrowband and two broadband filters are compared

• $1 + z = \frac{\lambda_{\text{obs}}}{1216 \text{Å}}$
Confusion in the Literature

• Past mean stacking analyses find typical LAEs at $z=3.1$ to have ages as young as 0.15 Gyr and as old as 1.6 Gyr (Gawiser et al. 2007; Lai et al. 2008)

• Using individual LAEs at $z=3.1$ other studies found these objects to be much younger (age < 0.1 Gyr) (Ono et al. 2010a)

• Another stacking study found LAEs at $z=3.1$ to be older than LAEs at $z=2.1$ (Acquaviva, Vargas, Gawiser, Guaita 2011)

• **We aim to ultimately answer the question: Is stacking an accurate way of analyzing LAEs at high redshift?**
The Data

- **MUSYC LAE Catalog** (Guaita et al. (2011))
  - 260 LAEs at z=2.1
  - GOODS-S

- **CANDELS** Multi-wavelength Catalog
  - GOODS-S Deep Region & ERS (~2/3 of entire GOODS-S)
  - Deep Photometry and imaging (UV to IR)
  - Catalog Matching produced 20 counterparts (0.5``)
Figure 1: The sample
How Do We Study LAEs Despite Low S/N?

Stacking!

Image Stacking

Flux Stacking
Types of Stacks

• Flux Stacks
• Image Stacks
  • HST – Centered
  • NB – Centered
• Scaled Stacks (Flux only, for now)
SED Fitting

• MCMC fitting of galaxy Spectral Energy Distributions (SEDs) provides insight to properties
  • SpeedyMC by Dr. Viviana Acquaviva

• Used to compare data to template of known characteristics

• Products: probability distributions for age, stellar mass, dust content (E(B-V))
Age vs Stellar Mass

$\rho_{\text{pearson}} = 0.8113$  
$\rho_{\text{spearman}} = 0.8361$  
$p_{\text{pearson}} = 1.4222 \times 10^{-5}$  
$p_{\text{spearman}} = 0.0000$

![Graph showing the relationship between age and stellar mass with correlation coefficients and statistical significance.](image-url)
Figure 5(b) shows a scatter plot of E(B-V) versus stellar mass on a log scale. The plot includes Pearson's correlation coefficient (ρ_pearson) and Spearman's rank correlation coefficient (ρ_spearman) for both correlation coefficients. The Pearson's correlation coefficient is given as ρ_pearson = 0.3060 and ρ_pearson = 0.1895, while the Spearman's rank correlation coefficient is given as ρ_spearman = 0.2226 and ρ_spearman = 0.3440.
E(B-V) vs Age

\[ \rho_{\text{pearson}} = 0.6516 \quad \rho_{\text{spearman}} = 0.5910 \]

\[ p_{\text{pearson}} = 0.0019 \quad p_{\text{spearman}} = 0.0071 \]
Conclusions

- Some stacks are slightly better than others
- ALL stacking misses dispersion of properties
- Scaled Stacks are Recommended

ArXiv: 1309.6341