UNDERSTANDING STELLAR POPULATIONS IN LYMAN ALPHA GALAXIES

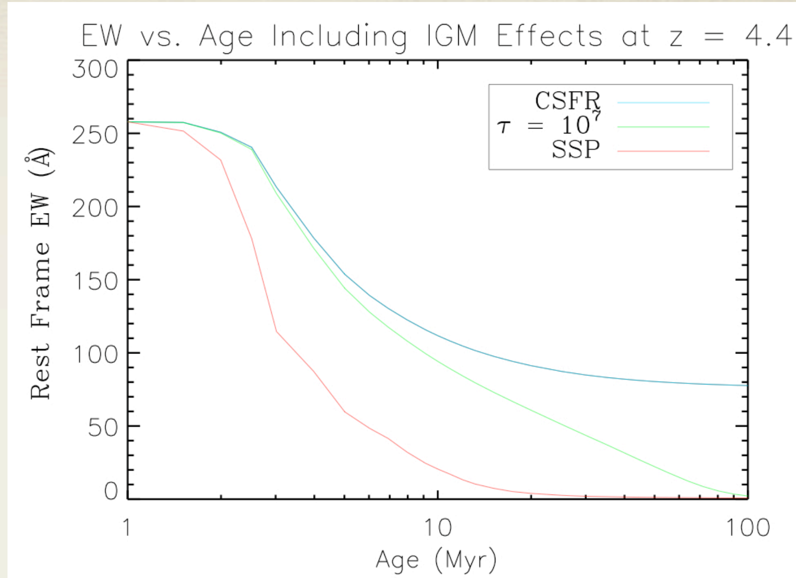
Steven Finkelstein

George P. and Cynthia W. Mitchell Institute for Astronomy and Fundamental Physics
Department of Physics and Astronomy
Texas A&M University

Collaborators: James Rhoads, Sangeeta Malhotra (ASU), Norman Grogin (STScI), Nimish Hathi (UC Riverside)

Motivation

* Many surveys for Lyα emitting galaxies (LAEs) have found stronger than expected Lyα equivalent widths (EWs).
  * e.g., Kudritzki et al. 2000; Malhotra & Rhoads 2002; Dawson et al. 2007; Finkelstein et al. 2007



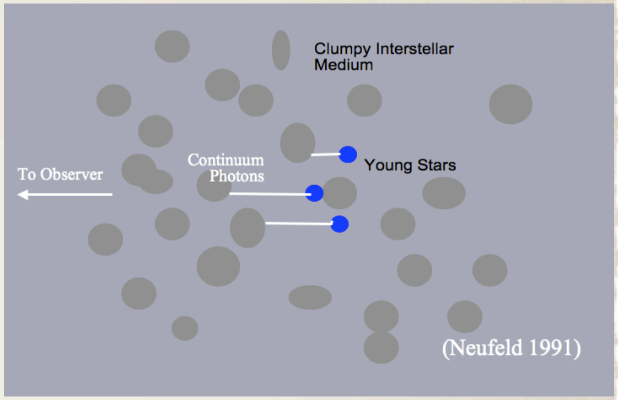
* Normal stellar populations require very young ages to produce the EWs that have been observed.
* Figure shows EW vs. Age for Salpeter IMF, Z = 0.02Z⊙.
* Peak EW of 260 Å at 1 Myr
* To see EW > 240 Å, must observe at t < 3 Myr.
* Highly unlikely to see large fraction of sample in first few Myr...

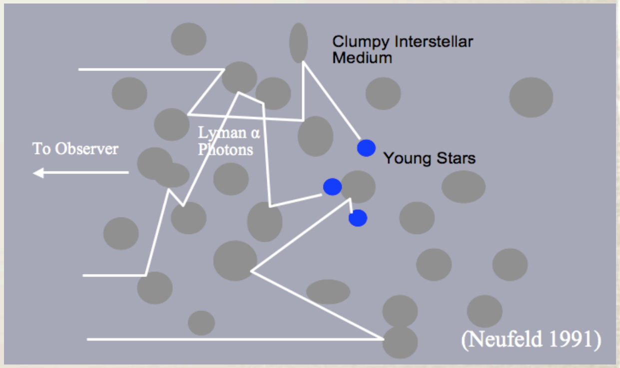
How to Increase your Lyα EW

- Three ways: Easy, Medium and Hard.
  - Easy: Just turn up your star formation!
    - More SF $\rightarrow$ (Massive stars) more ionizing photons $\rightarrow$ (Case B - 2/3) more Lyα photons.
    - Alternatively, you can tweak your IMF to create more massive stars (top-heavy IMF).
  - Medium: Turn on an AGN
    - AGN do exhibit strong Lyα lines, but usually only comprise a very small fraction of narrowband samples.
  - Hard: Decrease the number of continuum (not Lyα!) photons...
    - How? Dust!

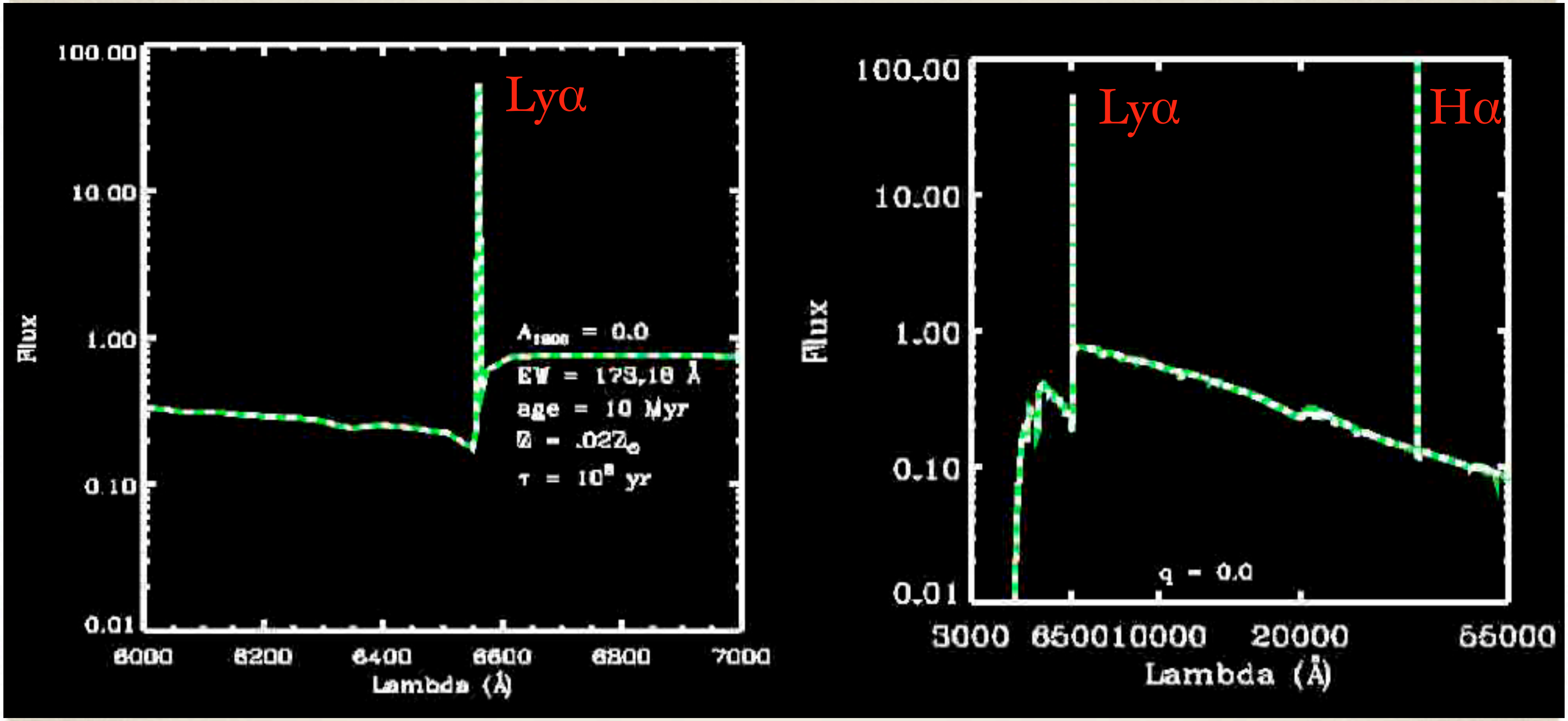
Dust Enhancement

- Dust was originally proposed as the reason why LAEs evaded detection in the 80’s and early 90’s (Meier & Terlevich 1981).
  - In a homogeneous ISM, Lyα photons have very short path lengths, thus they stand a high chance of being absorbed by dust if present.
- If the ISM is inhomogeneous, with the dust and H together in clumps, the Lyα photons may have an easier time escaping than continuum photons (Neufeld 1991; Hansen & Oh 2006).
  - Lyα scatters at the surface, while continuum photons penetrate the clump deeply, standing a much higher chance of encountering dust..
- Thus, Lyα has a higher escape fraction, increasing the EW.





* Zoomed in
* Full Spectrum

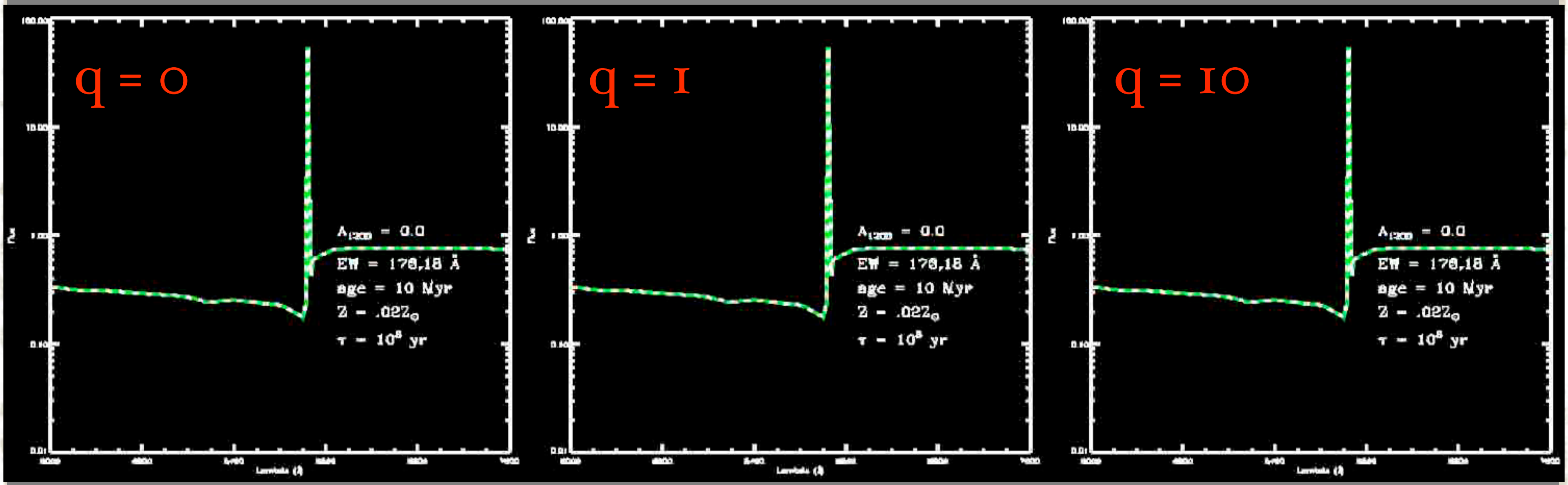


* Model spectrum of LAE at z = 4.5
    * 10 Myr, $Z = 0.02 Z_{\odot}$ - Initial EW = 173 Å

LAE Sample

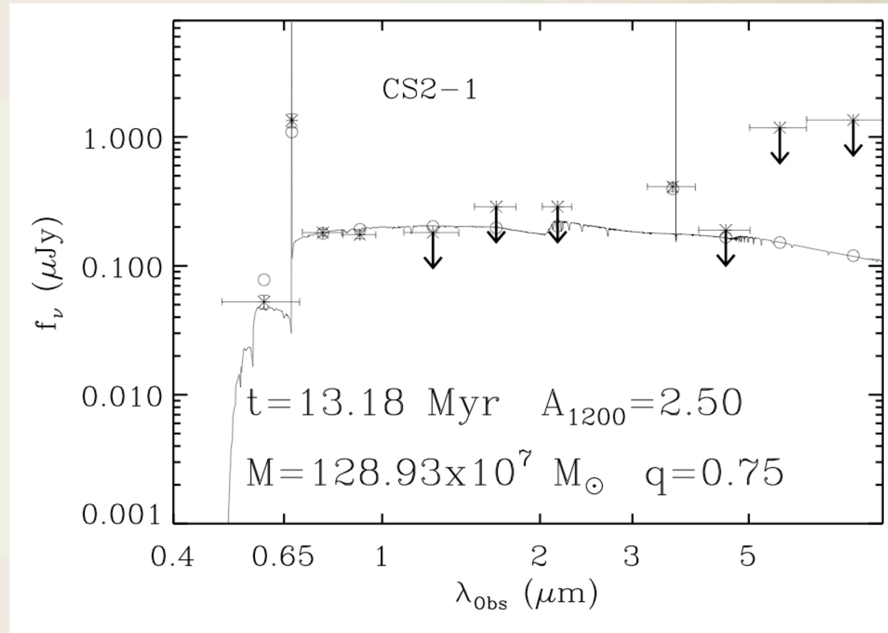
- We fit stellar population models to a sample of 14 CDF-S LAEs at z ~ 4.5 (Finkelstein et al. 2008a, 2009a).
  - Narrowband selected, using NB656 (Hα), NB665 (Hα+80) and NB673 ([SII]) imaging from CTIO Blanco + MOSAIC II.
    - Used GOODS-CDFS ACS and IRAC data, as well as upper limits from VLT/ISAAC.
- We used BC03 models, deriving the best-fit age, mass, metallicity, star formation history, and dust extinction (A_{1200}).
  - Included Lyα emission, with a geometry clumpiness parameter ("q") ranging from 0 - 10.
    - Dust attenuation: $f'_{Ly\alpha} = f_{Ly\alpha} * e^{-q\tau}$ $f'_c = f_c * e^{-\tau}$
      - q = 10 simulates homogeneous ISM, q = 0 simulates Neufeld scenario.

Clumpiness Parameter



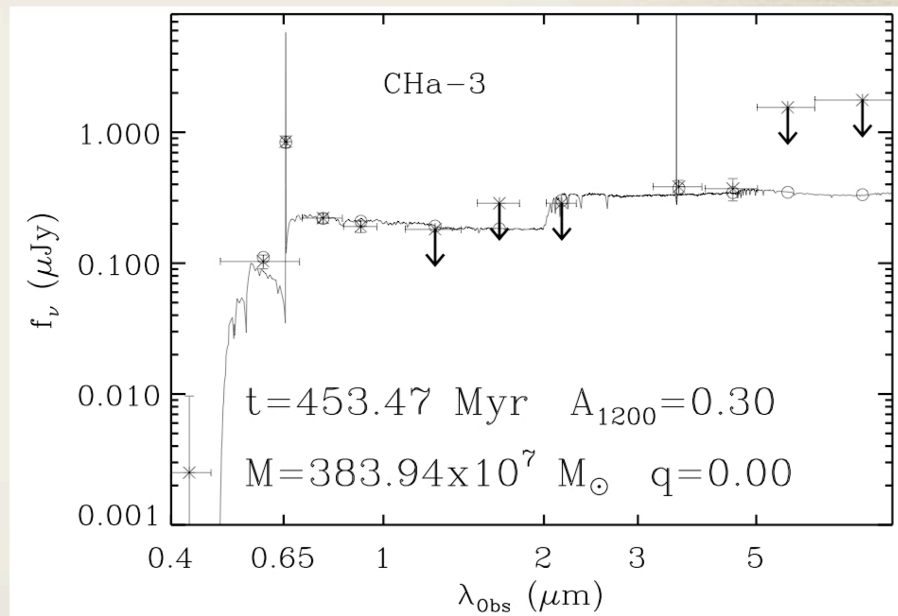
Results: Young LAE

- Results for CS2-1. Selected in NB673 ([SII]) filter; z ~ 4.52.
  - Arrows denote 3 σ upper limits.
- NB673 + ACS i' constrains Lyα emission.
- 3.6 - 4.5 μm constrains Hα emission.
  - Strong Lyα and Hα emission imply young age.
  - Yet red i-z color implies dust, thus q < 1 is necessary to give strong Lyα emission.



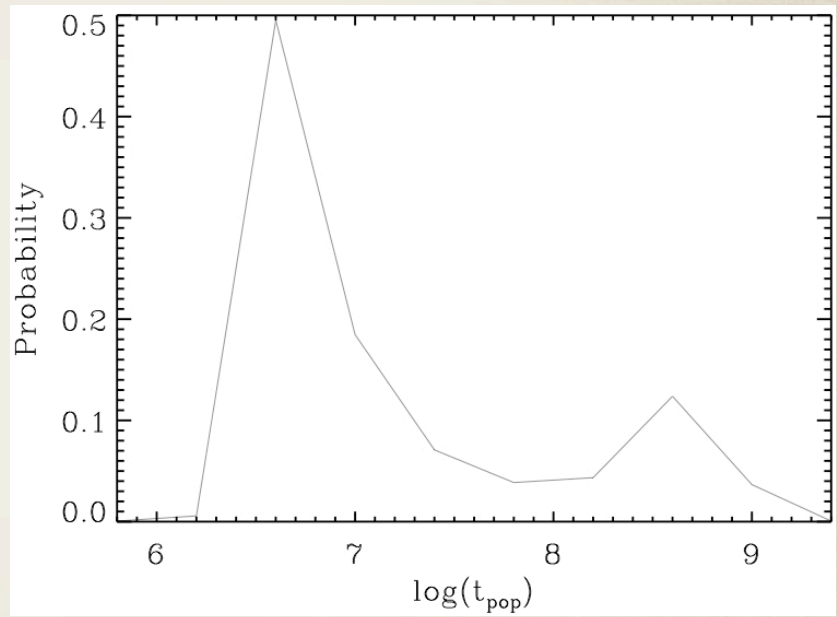
Results: Old LAE

- CHa-3 (z ~ 4.40) is best-fit by an old population.
  - Strong Lyα emission, yet weak Hα emission.
  - Also, J-band upper limit + IRAC data imply a strong 4000 Å break.
    - Both imply old stars.
  - Old stars + strong Lyα emission causes q < 1.
    - A galaxy this old likely needs dust enhancement to show a strong Lyα line.



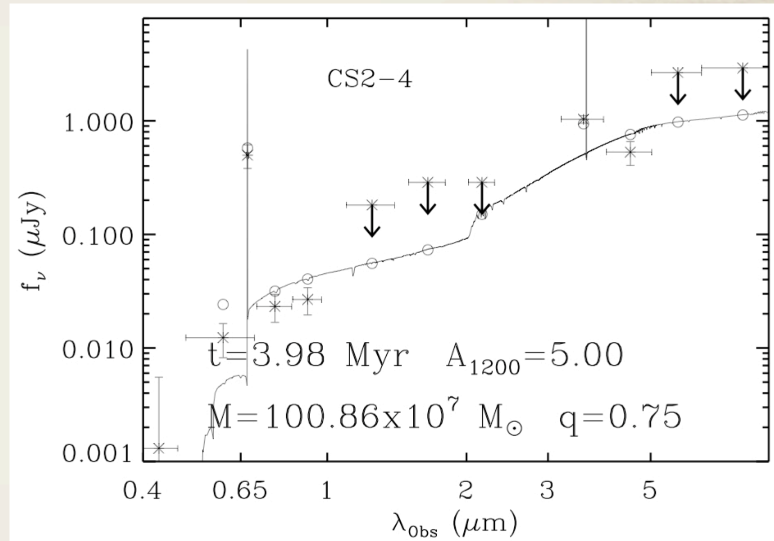
Age Distribution

- Out of our sample of 14 objects, 12 are best fit by young populations (similar to CS2-1), and two are best-fit by old populations (similar to CHa-3).
    - To examine this difference, we ran 7000 Monte Carlo simulations, obtaining a best fit in each simulation.
- The resulting age distribution shows that our objects fall into two age regimes: young (< 15 Myr), or old (> 400 Myr).
    - We need a much larger sample to see if this effect is real.



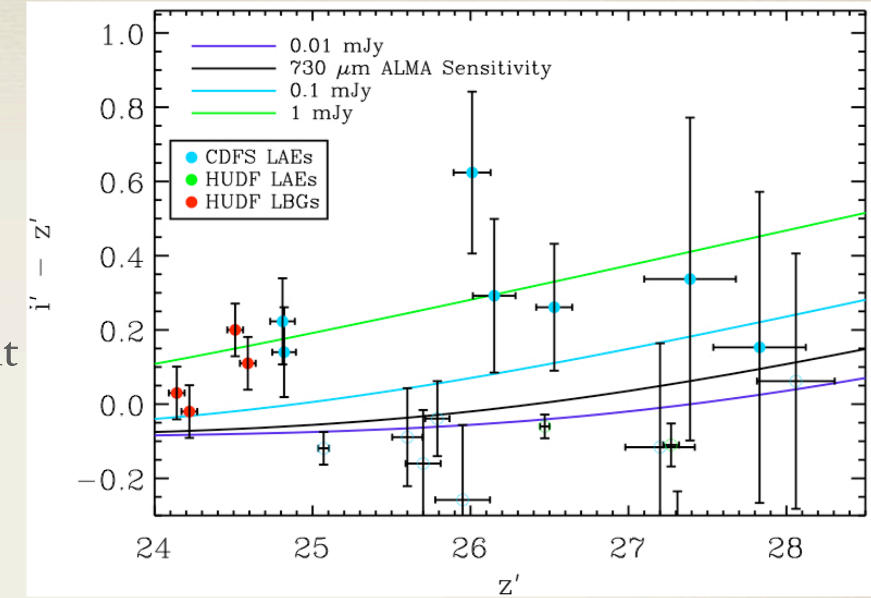
How can we do better?

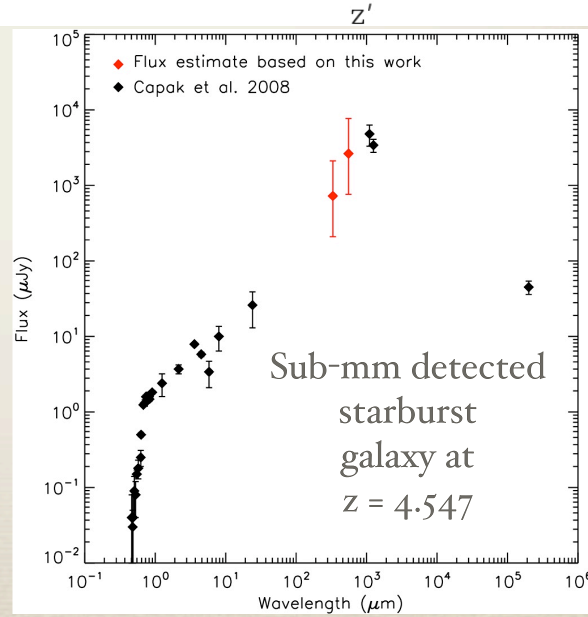
- Lack of detections in the NIR hampers our ability to accurately fit the age.
    - Cannot well constrain the amplitude of the 4000 Å break.
    - Example: This object can either by fit by a young population with 5 mag of dust extinction, or an older population with less dust.
- *Spitzer* fluxes have uncertainty due to broad PSF.
    - Both of these should be fixed with JWST.
- In the meantime, we can learn more at lower redshifts, where the objects are brighter, and these critical wavelength regimes get shifted closer to the observed optical.



How can we do better?

- If one knows any of the model parameters *a priori*, then the other parameters become better constrained.
    - Red colors caused by dust, old stars, Z...
- One can measure the amount of dust present if one can measure the dust emission, which peaks ~ 100 µm.
    - At z ~ 4.5, this is shifted to the sub-mm.
- Using a relation from Meurer et al. 1997, we were able to convert the UV spectral slope (from i - z or J - H colors) into the FIR excess, the thus the FIR flux.
    - We then compared these fluxes, observed at ~ 0.5 mm, to the expected sensitivity of ALMA.
    - ALMA should be able to detect dust emission from 39% of a sample of 23 LAEs (Finkelstein et al. 2009b).





Conclusions

* Many LAEs contain dust ➜ LAEs ≠ primitive.
* A clumpy, dusty ISM can explain the observed SEDs of LAEs at z ~ 4.5 without invoking a top-heavy IMF or Pop III stars.
    * 10/14 LAEs best fit by dust enhancing Lyα.
* Need NIR detections and higher resolution IR to increase fidelity of models.
    * JWST will help with this.
* ALMA should detect dust emission from a large fraction of LAEs.
    * Independent test on dust.