Tracing molecular gas mass with [CII] in z ~ 6 galaxies

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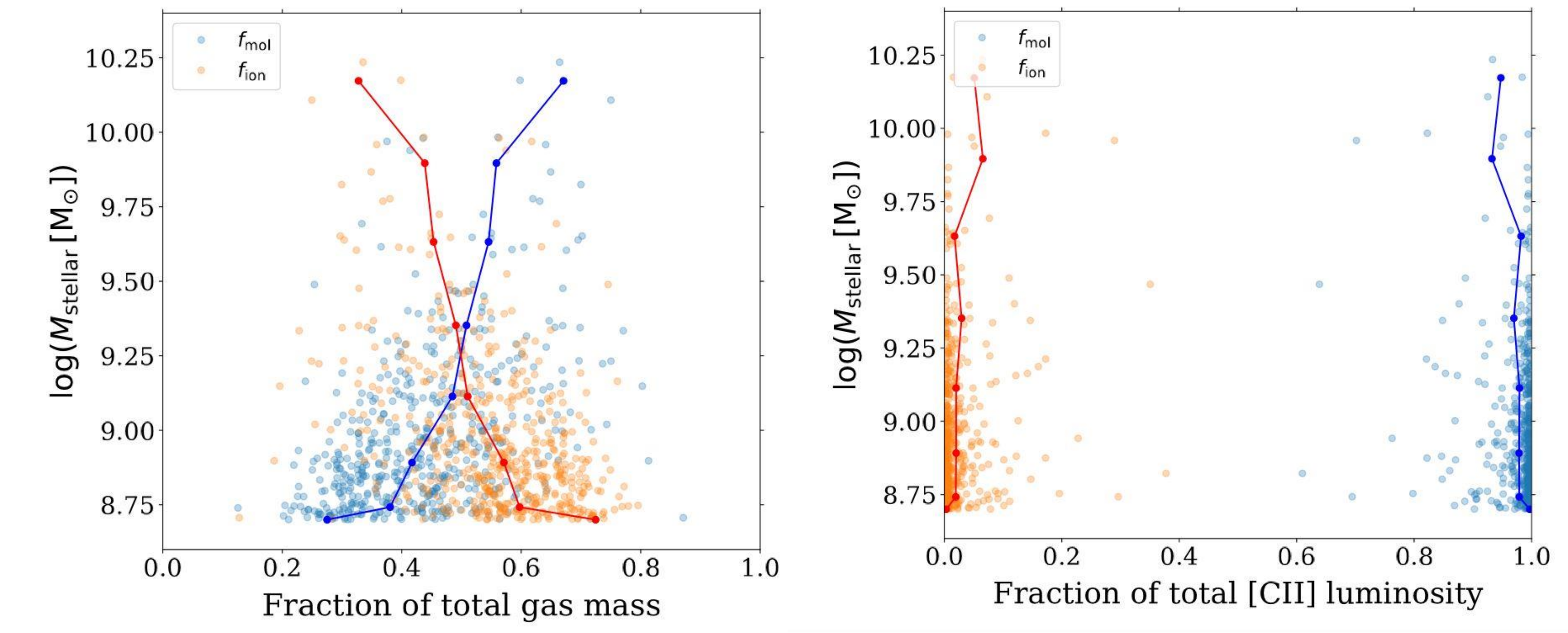
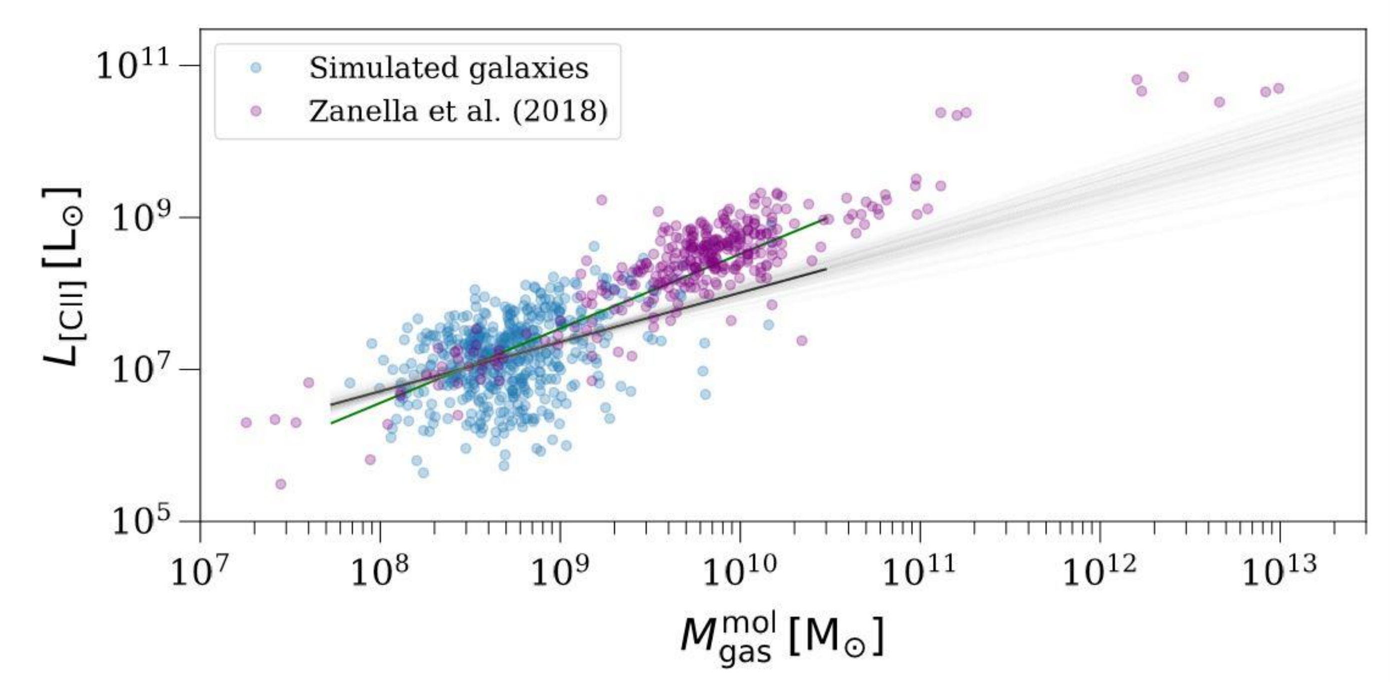
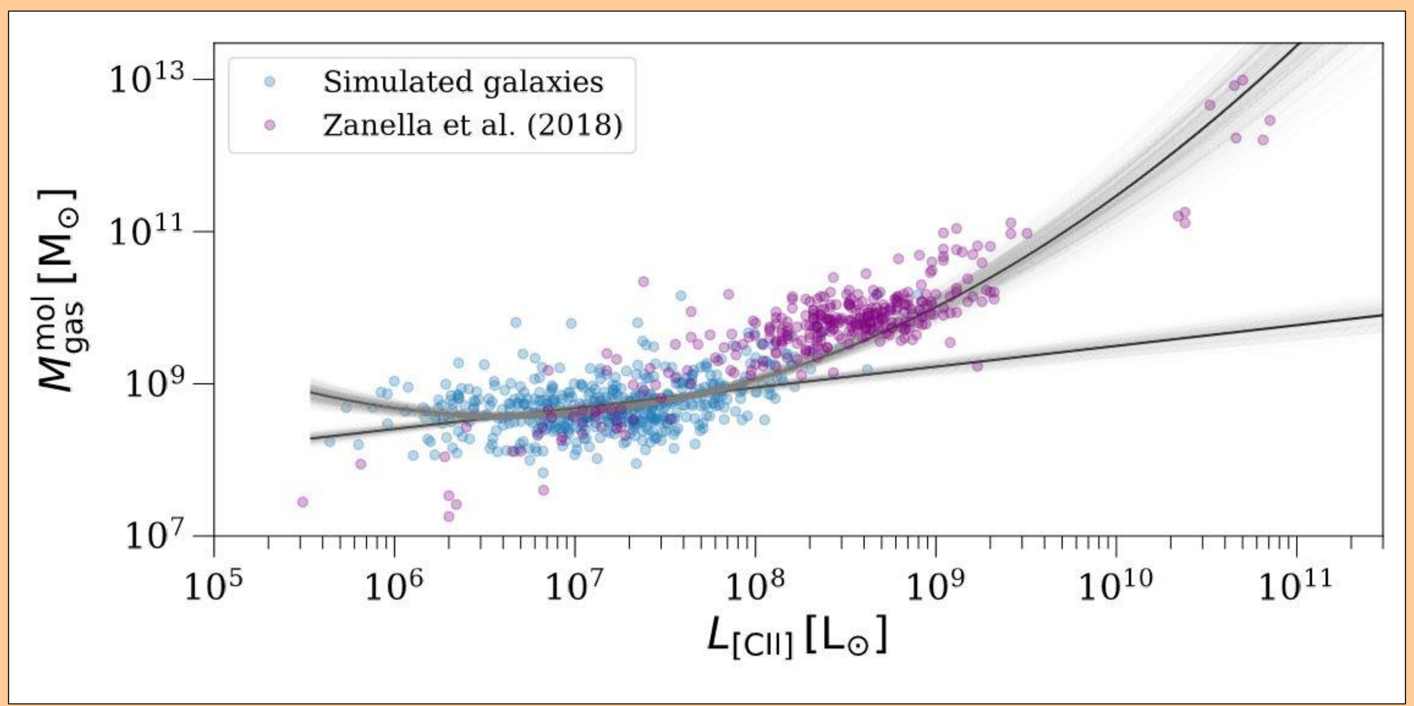
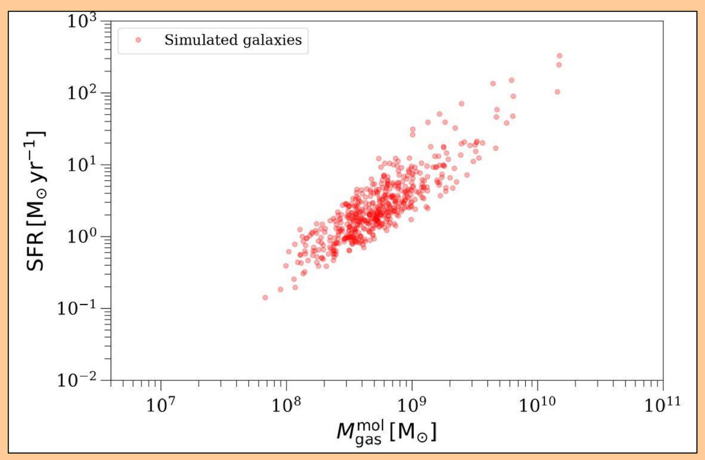
Motivations

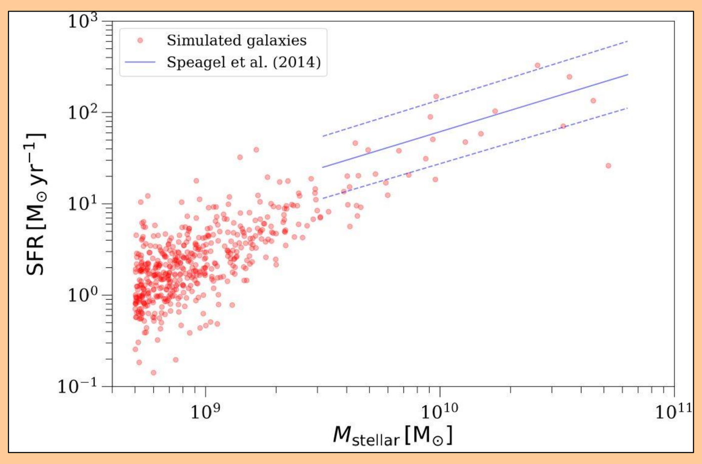
- Little is understood about the "epoch of reionization" and the galaxies which formed during this epoch
- Measuring the gas masses of these galaxies will allow astronomers to create models of how galaxies build up in gas mass over time, and how this evolution influences other quantities such as star formation rate (SFR) and metallicity
- The canonical gas mass tracer in galaxies, CO(1-0), is difficult to observe at z > 6 other than in the most luminous galaxies. [CII] @ 158 μm is one of the brightest emission lines in galaxies and redshifts into observable submillimeter bands at high redshifts; thus it may have tremendous potential to trace gas mass.
- **Goal: derive molecular gas mass from [CII] luminosity.**











Galaxy sample & main method

- The galaxy sample was created using SIGAME (Simulator of Galaxy Millimetre / submillimeter Emission) (Olsen et al. 2015, 2016, 2017).
  - *The sample consists of 845 galaxies with M_{star} > 5 x 10^8 solar masses and accounts for diffuse (> 99% ionized gas) and molecular gas phases*
  - *The sample seems to follow the observed SFR-M_{star} main sequence (Speagle et al. 2014; see left, above) at higher stellar masses*
  - *Smooth particle hydrodynamics (SPH) simulations come from SIMBA (Davé et al. 2019)*
  - *Above figures: left shows a switch in the dominating gas mass phase at higher stellar masses of the galaxies; right shows that most of the luminosity is dictated by molecular gas*
- Simulated [CII] luminosities and molecular gas masses are used to derive a conversion factor for gas mass via fits over the parameter space.
- From simulations we describe a log-linear fit and 2nd order fit (*left, blue*) in the boxes below:

Conversion factors:

1st order

$$\log_{10}(M_{gas}) = (0.28 \pm 0.03)\log_{10}(L_{[CII]}) + (6.75 \pm 0.19)$$

2nd order

$$\log_{10}(M_{gas}) = (0.26 \pm 0.03)\log_{10}^2(L_{[CII]}) + (-3.40 \pm 0.45)\log_{10}(L_{[CII]}) + (19.85 \pm 1.61)$$

A multi-dimensional model?

- Projecting the above fits to a 3-dimensional space – with star formation rate (SFR) being the 3rd dimension – yields a curved plane (*right, bottom*)
- SFR is traced very well by molecular gas mass (*above, left*) and knowing SFRs of an observed galaxy would allow for a very precise estimate of gas mass
- In reality, this is not feasible; SFR is hard to measure on its own so it is impossible to derive gas mass from it
- Going into 4-dimensional space – with metallicity being the 4th dimension – did not seem to affect the fit in a meaningful way

The plan going forward

- We will constrain our sample further to account for observational limits etc.
- We intend to derive three conversion factors:
  - Simulations + observations: we will combine our sample with observed galaxy samples from lower redshifts (see Zanella et al. 2018 etc.) to derive a fit similar to those above
  - Simulations only: remodeling the fits above using a different cut of the sample
  - Observations only: for example, Zanella et al. (2018) derived a conversion factor for galaxies @ z ~ 2
- We will then use these conversion factors to derive molecular gas mass measurements for galaxies at z > 4 which have not been included in previous galaxy samples
- More work is also needed to quantify how much SFR and metallicity assist in estimating molecular gas mass

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References

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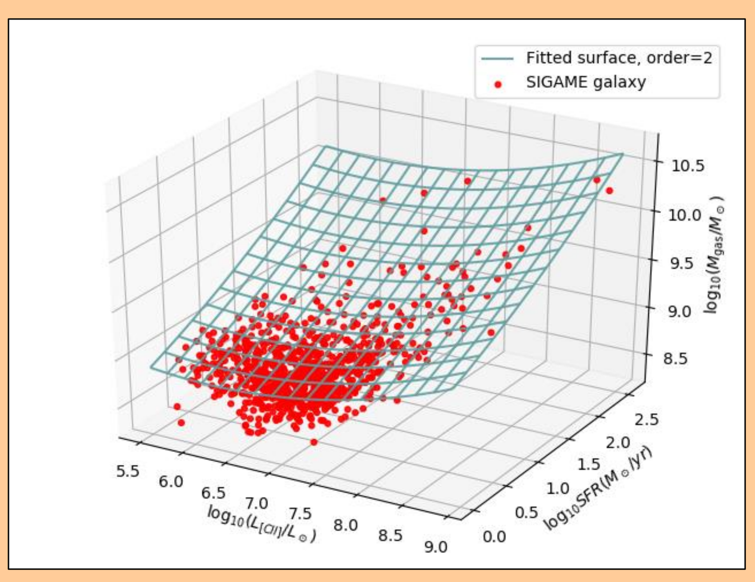

Acknowledgements & special thanks

- This project made use of Python and many packages, including numpy, pandas, matplotlib, scipy, and PyMc3, among many others.
- Special thanks to the Cosmic Dawn Center for its continued support throughout the research process, and to my friends & professors at Wesleyan University for their persistent support & kindness throughout the research process ☺