

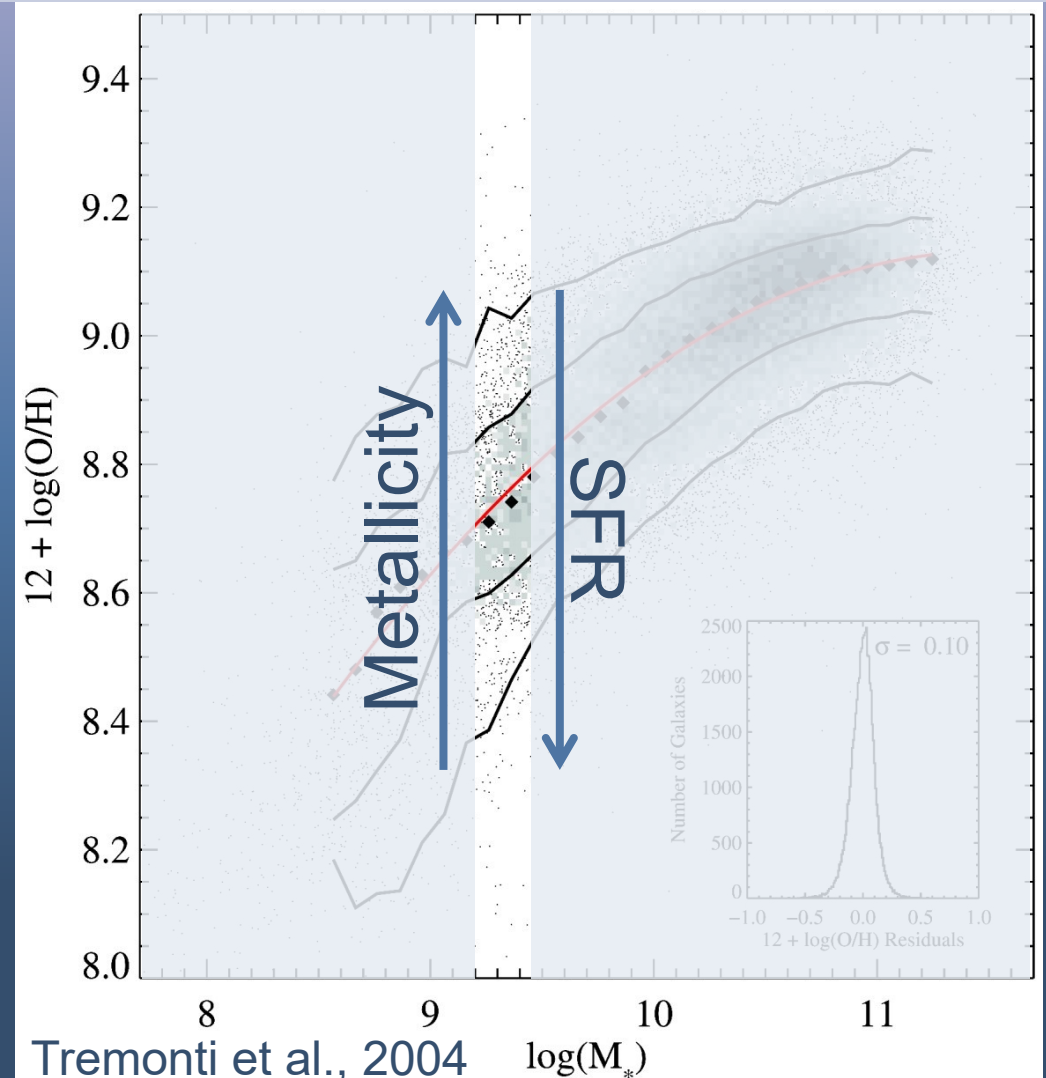
The Fundamental Metallicity Relation at $z \sim 2-3$: Complications from the Keck Baryonic Structure Survey

Nathalie Korhonen Cuestas, Strom Group

GALCROSS, 19/09/2024

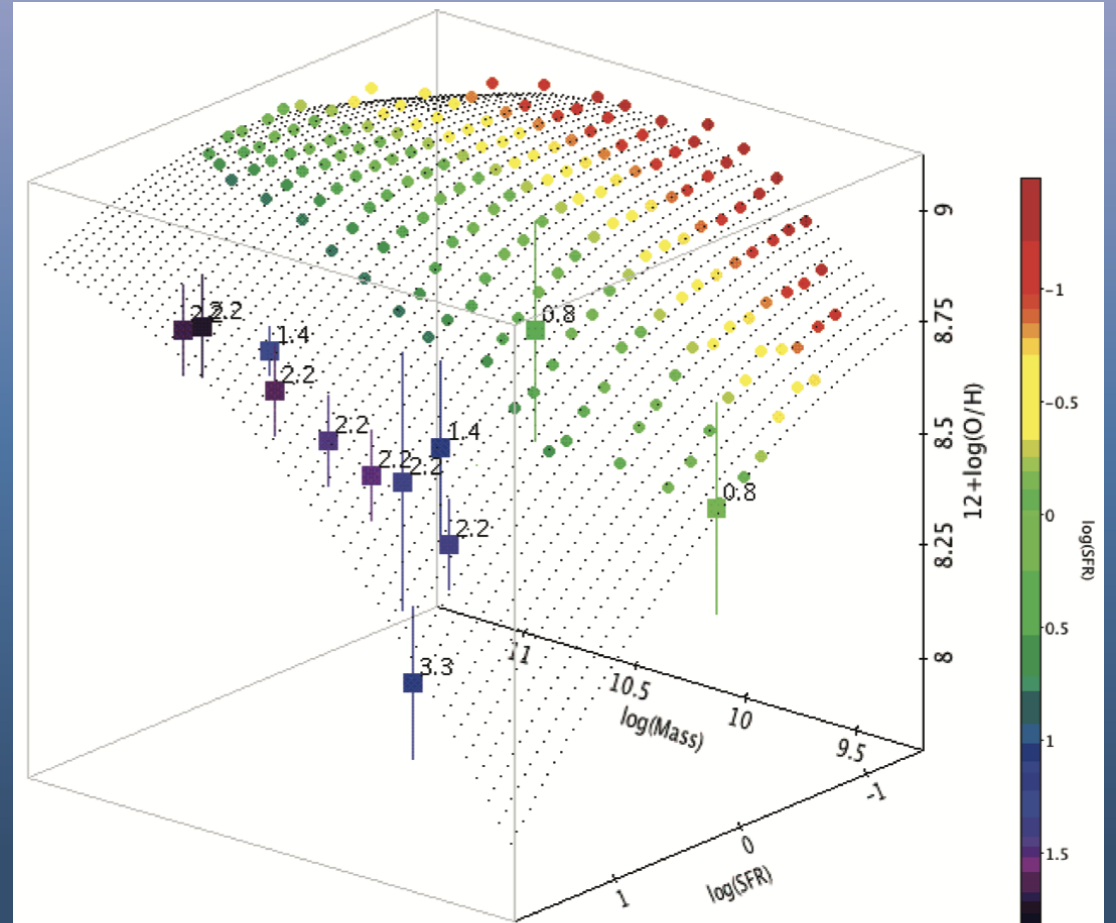
Scatter in the MZR

- MZR scatter is known to be correlated with SFR
- High SFR correlated with low metallicity



The Fundamental Metallicity Relation

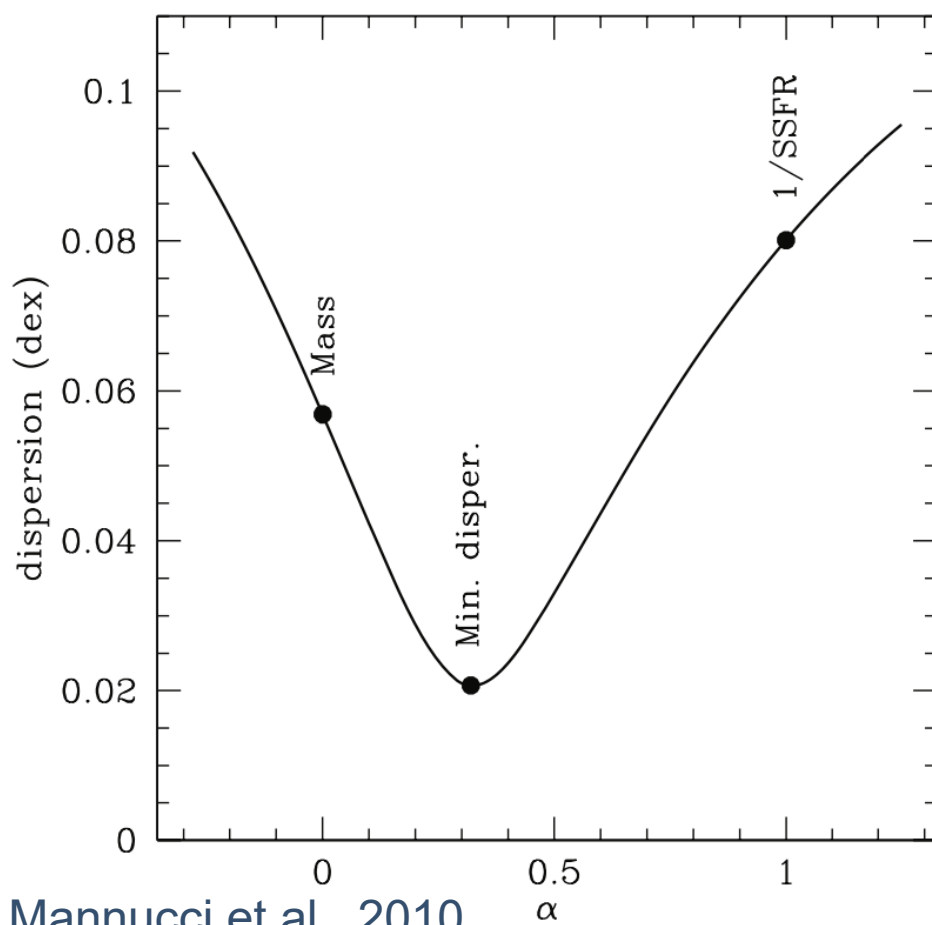
- One proposed form of a M-Z-SFR relationship
- 3D, redshift invariant surface



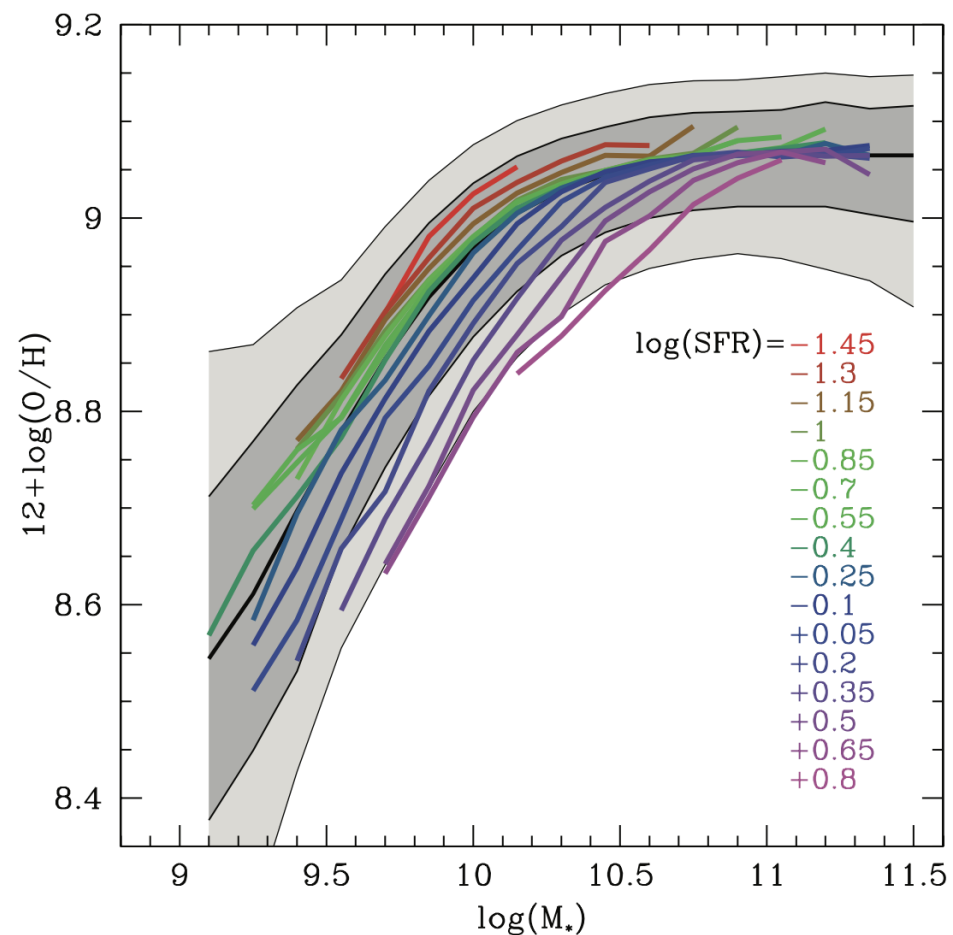
Mannucci et al., 2010

Parametric Approach

$$\mu_\alpha = \log M_\star - \alpha \log \text{SFR}$$

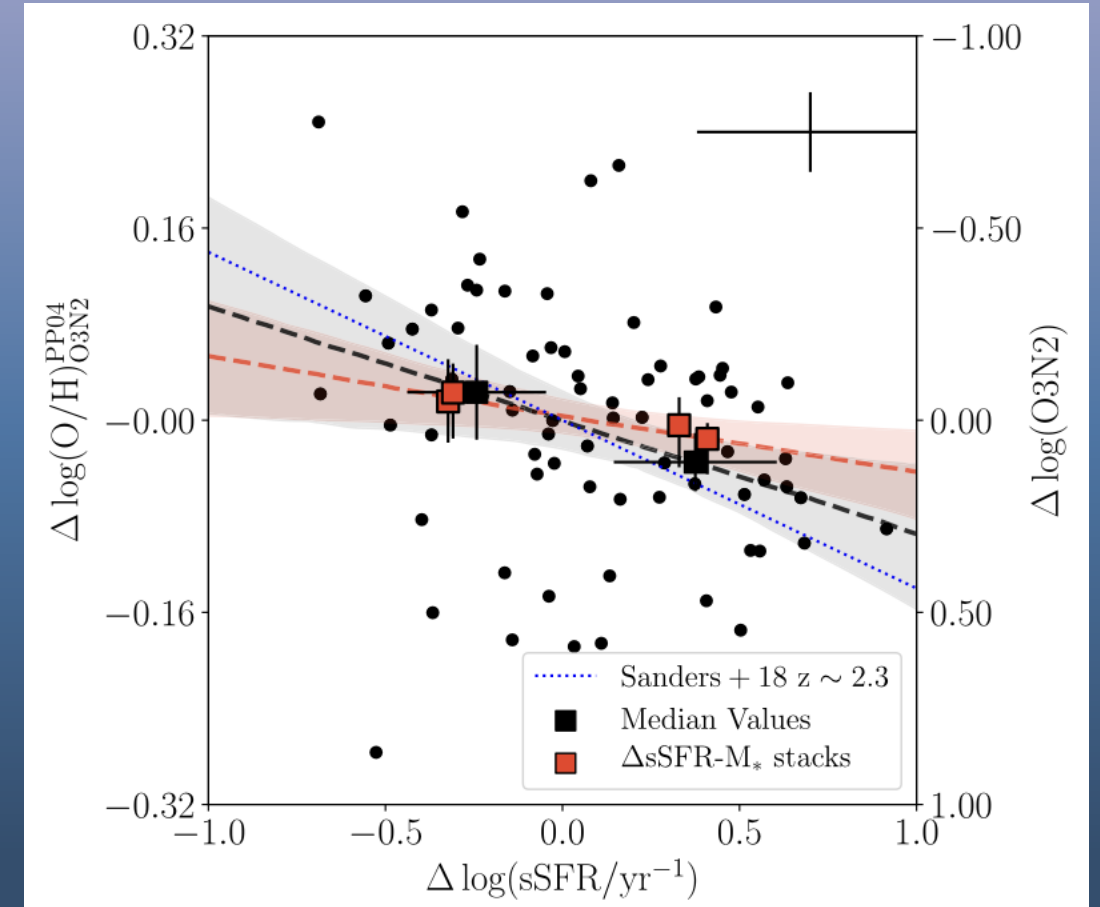


Mannucci et al., 2010



Non-Parametric Approach

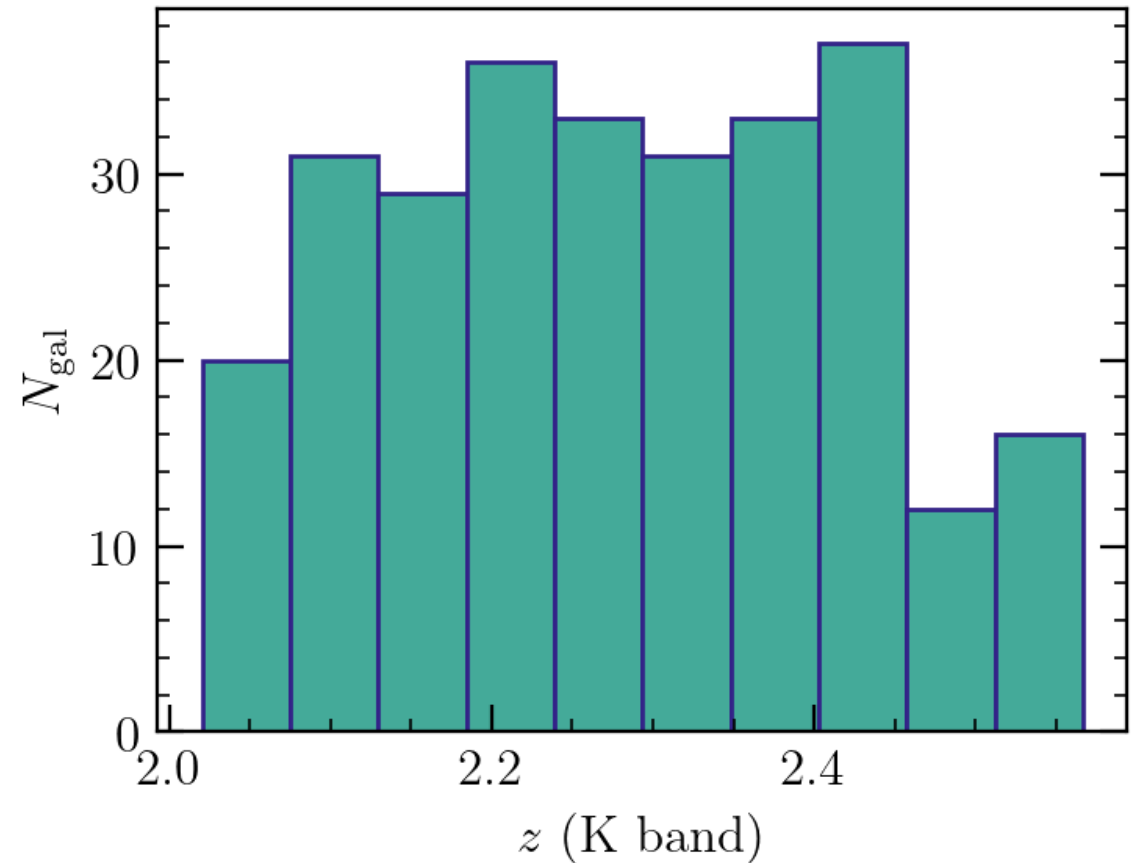
- Salim et al., 2014
- Quantifying correlations between excess metallicity and excess sSFR



Topping et al., 2021

The Keck Baryonic Structure Survey

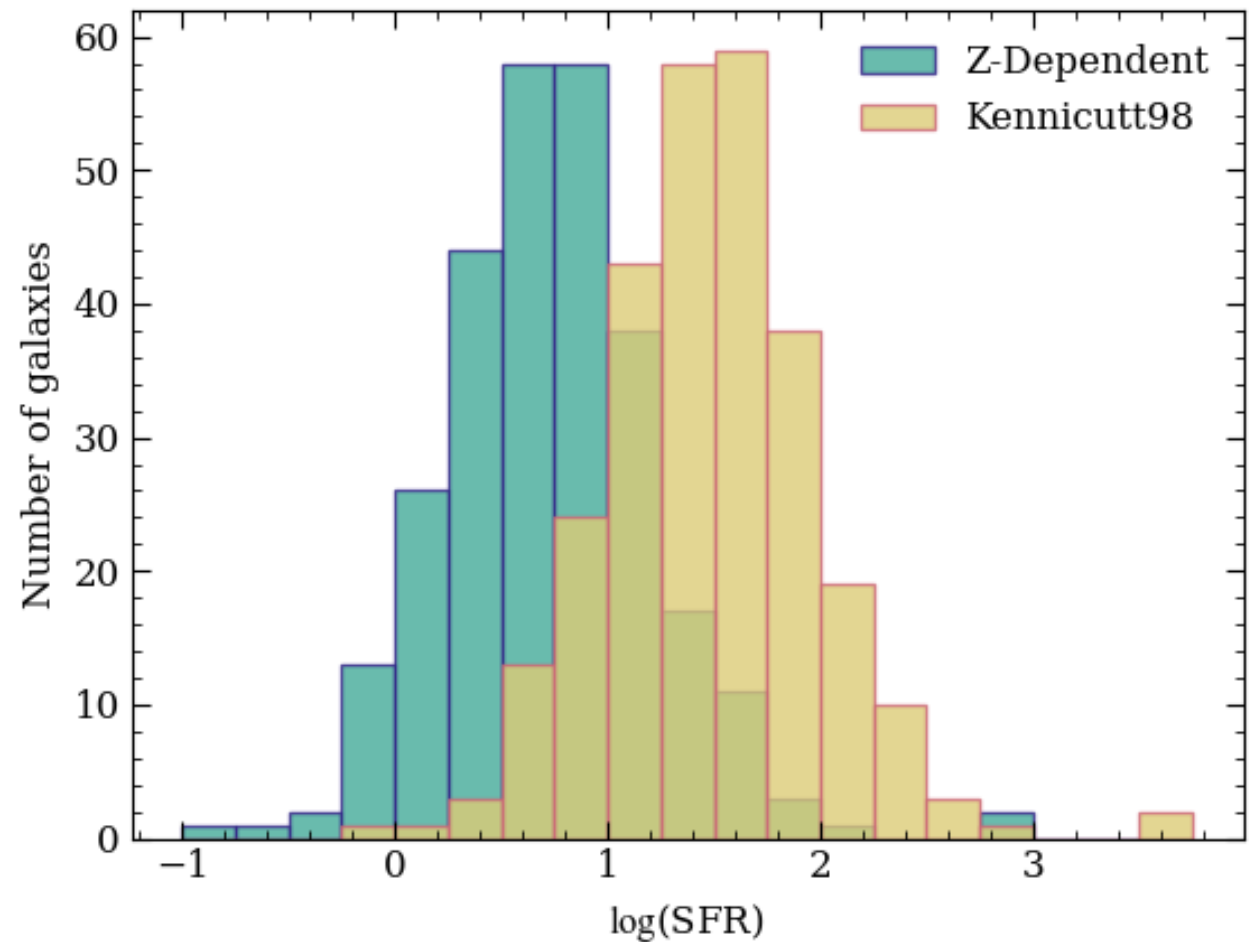
- Targeted survey aimed at observing $z \sim 2-3$ galaxies
- Rest-optical observed using MOSFIRE
- $N_{\text{gal}} = 278, z_{1/2} = 2.28$



Korhonen Cuestas et al., (in prep)

Metallicity-Dependent SFR

- Metal-poor stars produce more ionizing radiation
- $\log \text{SFR} = \log \mathcal{L}_{H\alpha} - \log \mathcal{C}(Z)$
- Considering the metallicity leads to a **systematically lower SFR**



Strong-Line Calibrations

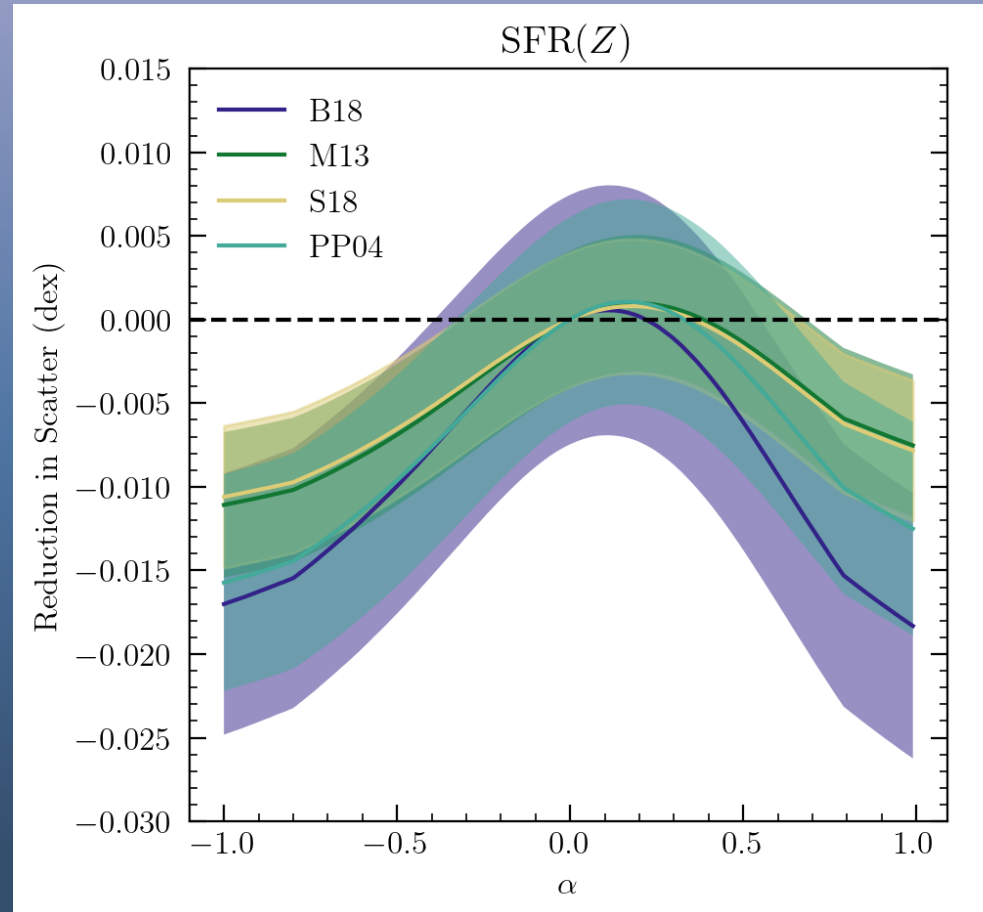
$$\text{O3N2} = \log\left(\frac{[\text{O III}]\lambda 5007}{\text{H}\beta}\right) - \log\left(\frac{[\text{N II}]\lambda 6585}{\text{H}\alpha}\right)$$

$$\text{N2} = \log\left(\frac{[\text{N II}]\lambda 6585}{\text{H}\alpha}\right)$$

- 4 O3N2 and 4 N2 calibrations based on
 - Local H II regions, local high-z analogues, or high-z galaxies
 - Direct electron temperature measurements, photoionization modelling, or a combination.

Parametric Approach

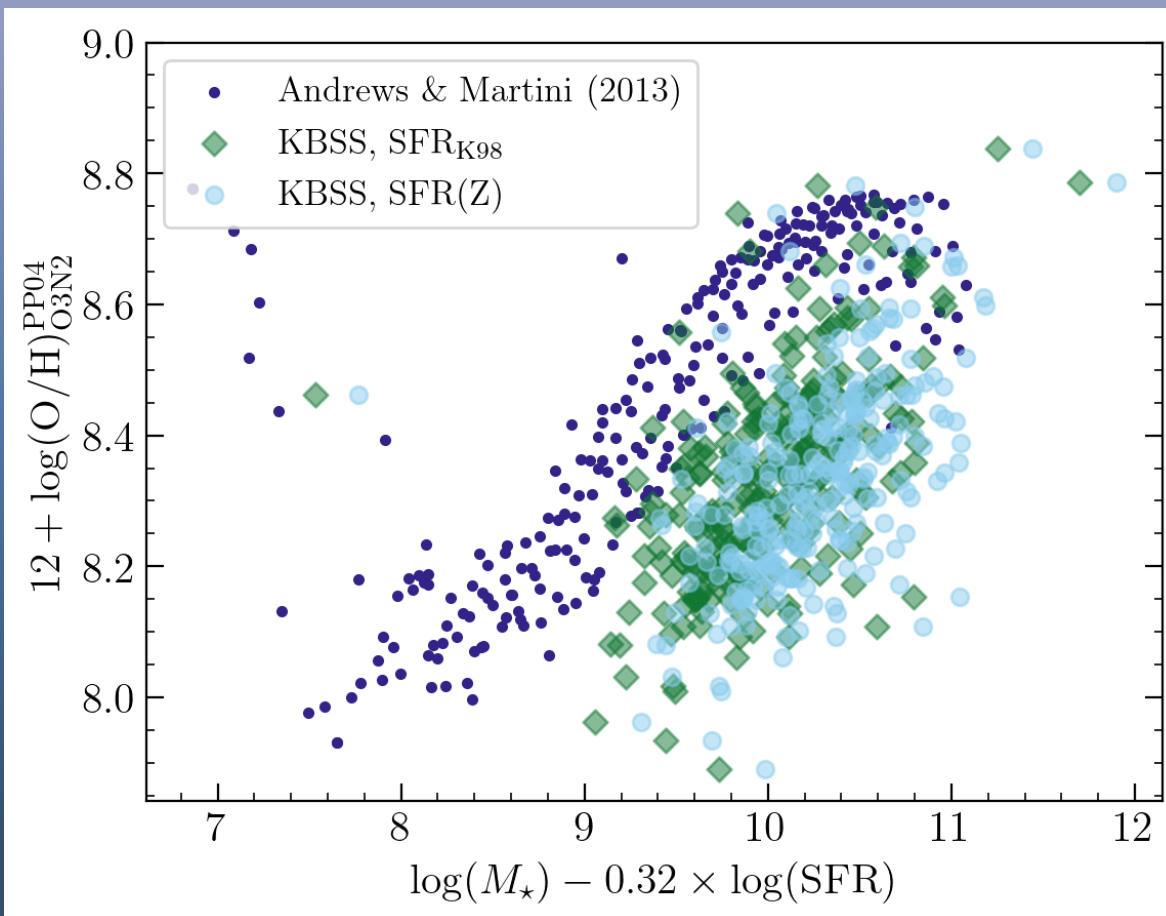
- $\mu_\alpha = \log M_\star - \alpha \log \text{SFR}$
- Estimate intrinsic scatter for $-1 \leq \alpha \leq 1$
- **No statistically significant reduction in scatter**



Korhonen Cuestas et al., (in prep)

Comparison to SDSS FMR

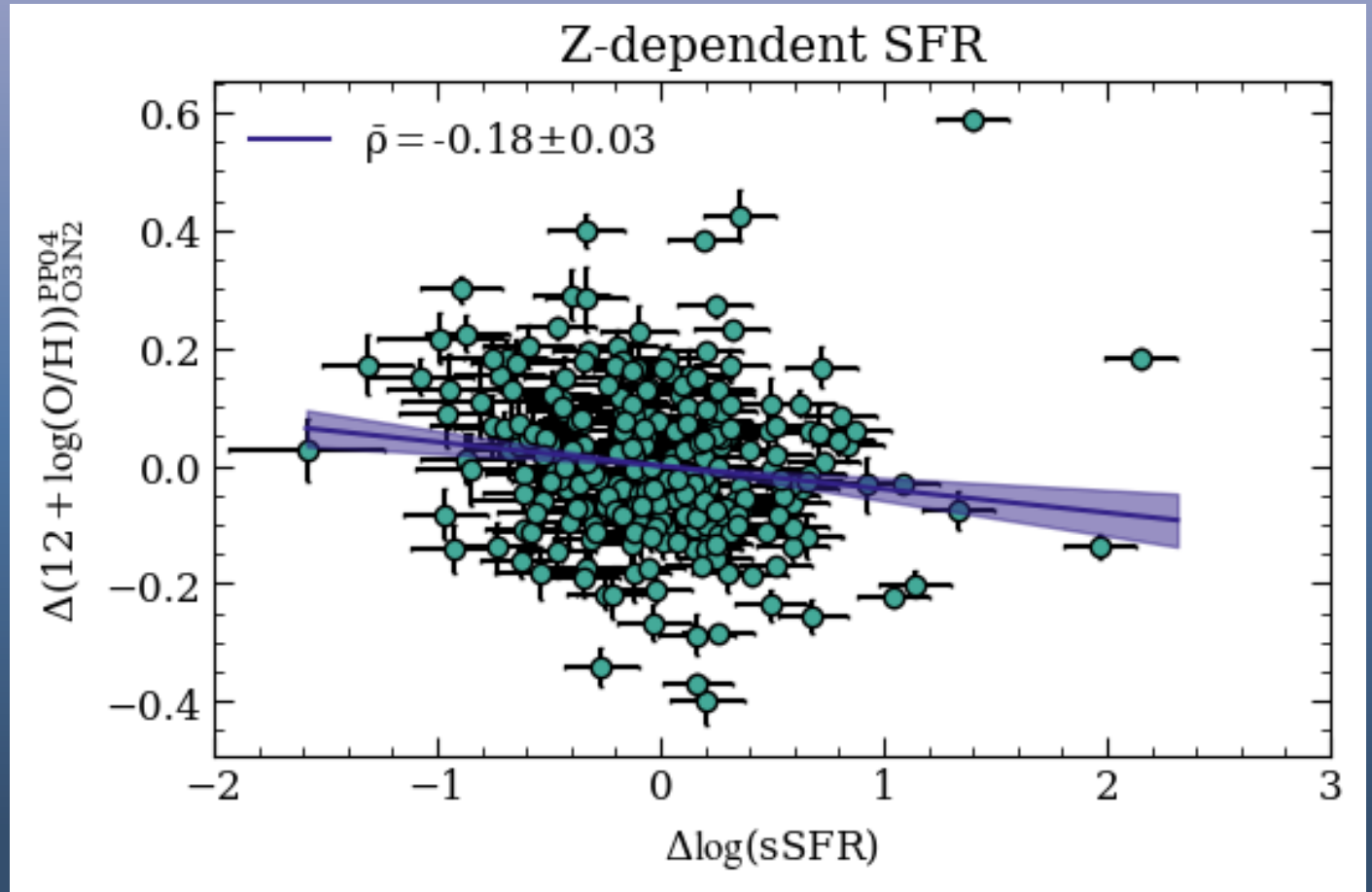
- Offset from $z \sim 0$ SDSS galaxies using the same calibrations
- Inconsistent with a redshift-invariant FMR



Korhonen Cuestas et al., (in prep)

Non-Parametric Approach

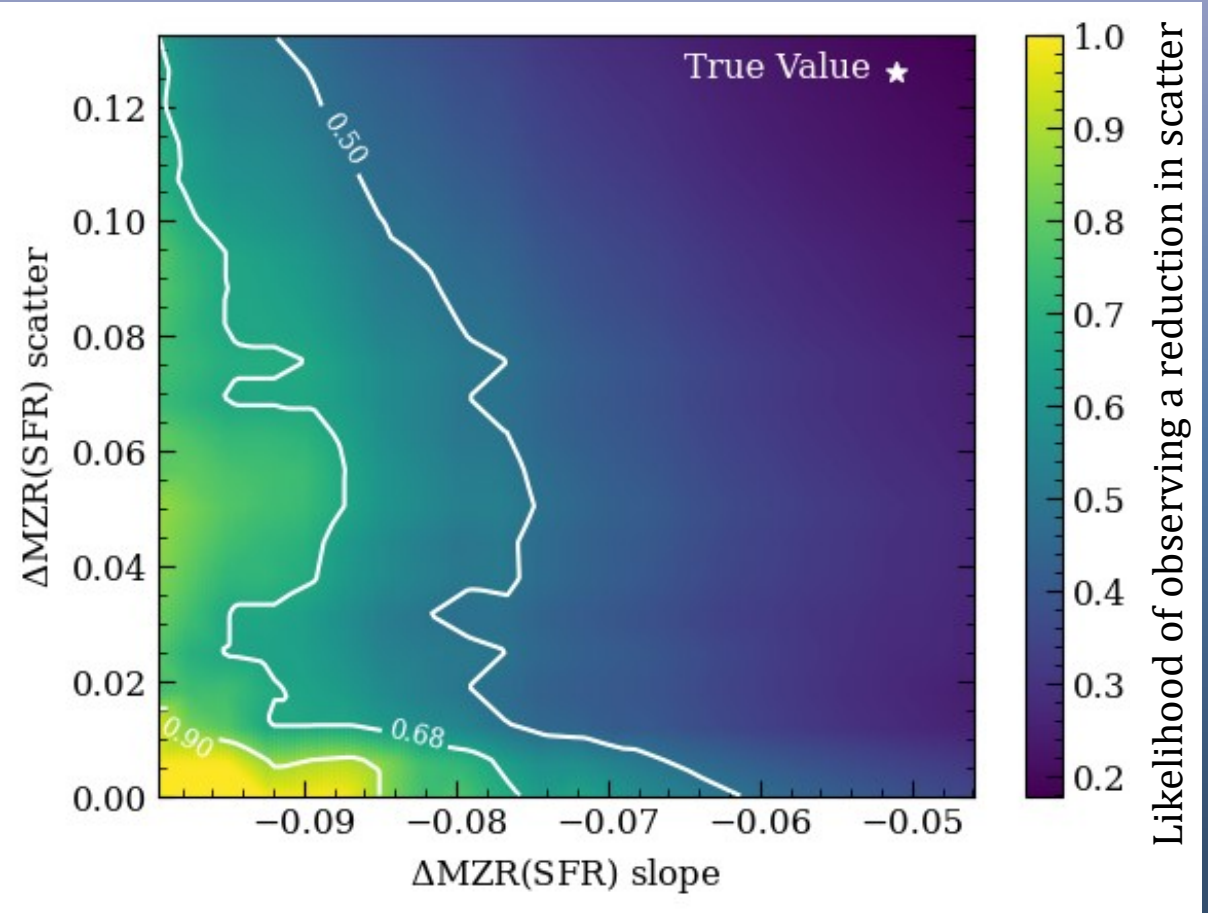
- Weak but significant correlation between excess oxygen abundance and excess sSFR
- Also seen between excess oxygen abundance and absolute SFR



Korhonen Cuestas et al., (in prep)

Understanding FMR vs. M-Z-SFR

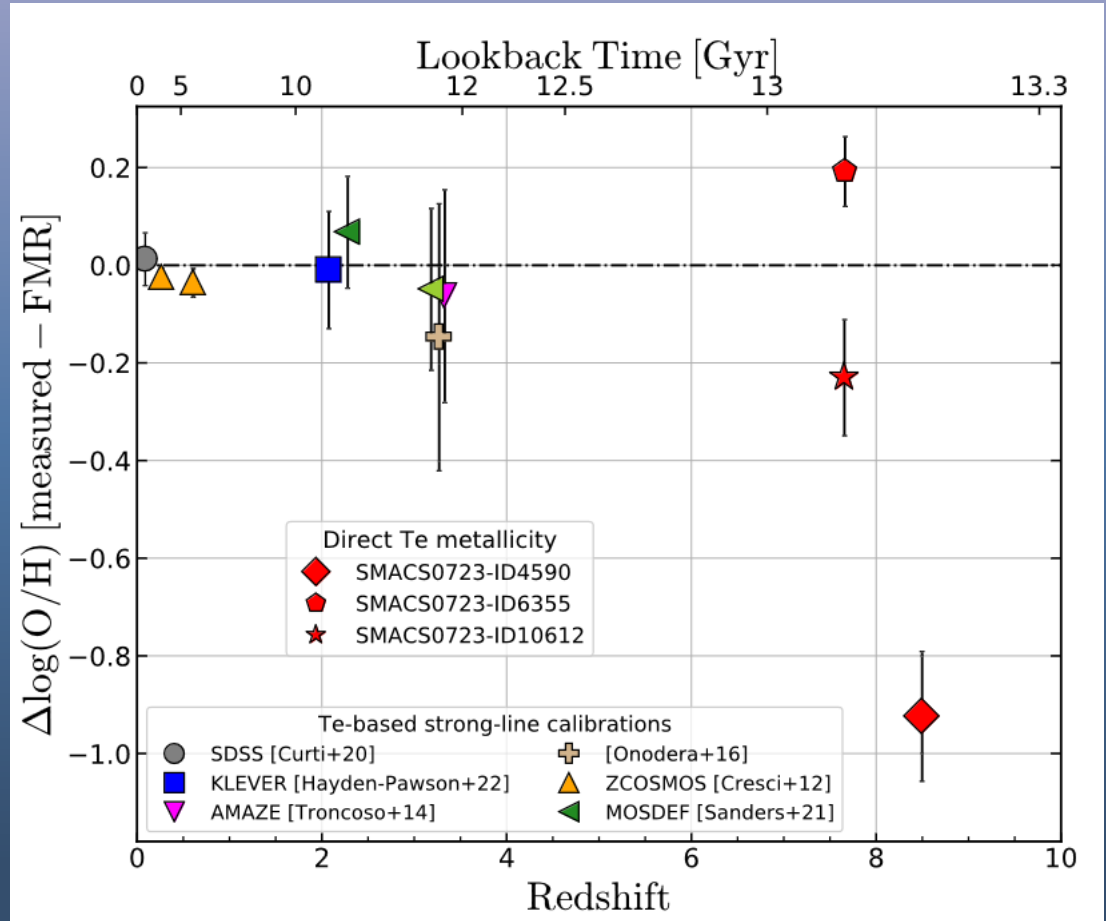
- To observe a significant reduction in scatter, **$\Delta\text{MZR}(\text{SFR})$ must have a steeper slope**
- KBSS is consistent with:
 - Redshift-dependent FMR
 - Weak SFR dependence



Korhonen Cuestas et al., (in prep)

Physical Implications

- Inconsistency with the FMR has been observed at higher redshifts
 - Rapid gas infall increases SFR but lowers the star formation efficiency
- At $z \sim 2.3$, some galaxies are still in a state of disequilibrium



Curti et al., 2023

Takeaways

Across SFR calculations and strong line calibrations:

1. KBSS galaxies are inconsistent with the local FMR.
2. KBSS galaxies show a weak but significant correlation between excess oxygen abundance and excess sSFR.
3. The FMR and a M-Z-SFR relationship are only synonymous when the correlation between excess oxygen abundance and SFR is stronger.
4. KBSS galaxies at $z \sim 2.3$ are not in equilibrium.

References

Andrews, B. H., & Martini, P. 2013, ApJ, 765, 140, doi: 10.1088/0004-637X/765/2/140

Mannucci, F., Cresci, G., Maiolino, R., et al. 2009, MNRAS, 398, 1915, doi: 10.1111/j.1365-2966.2009.15185.x

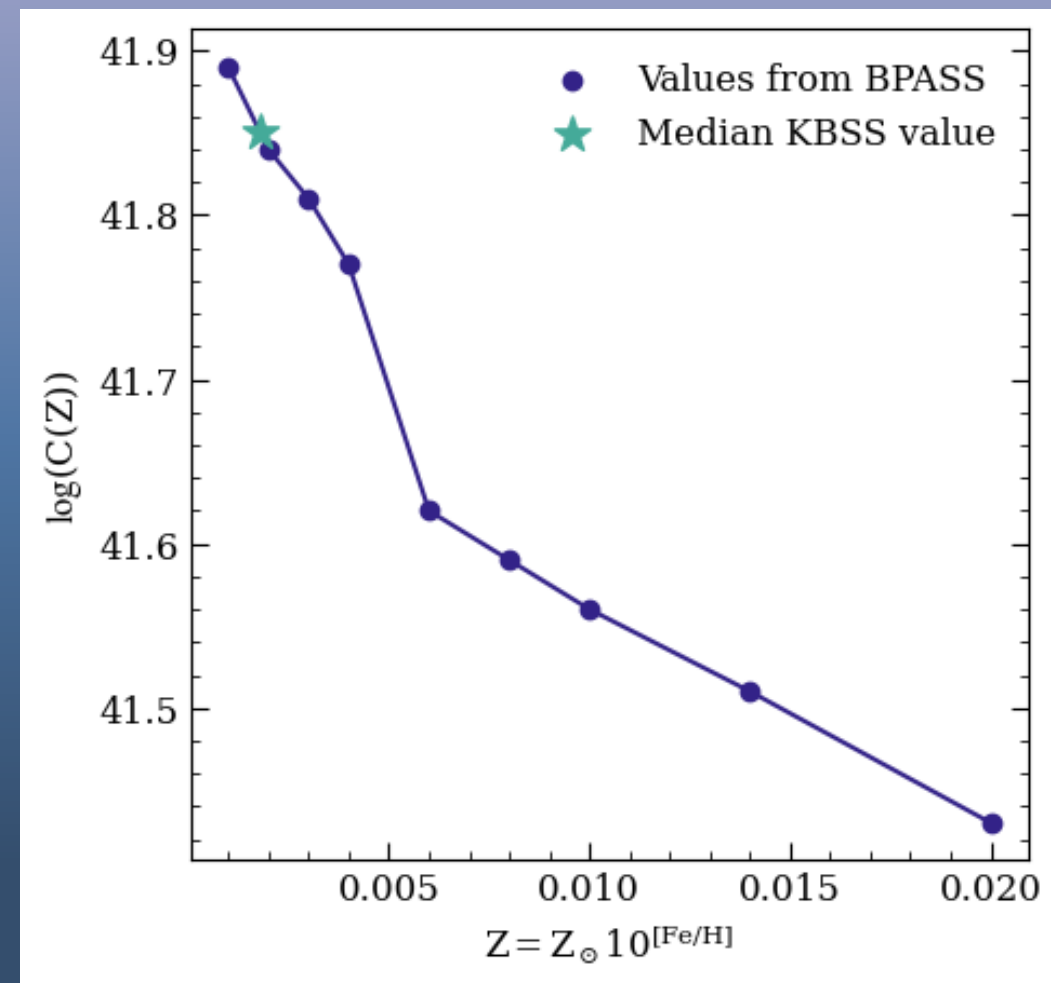
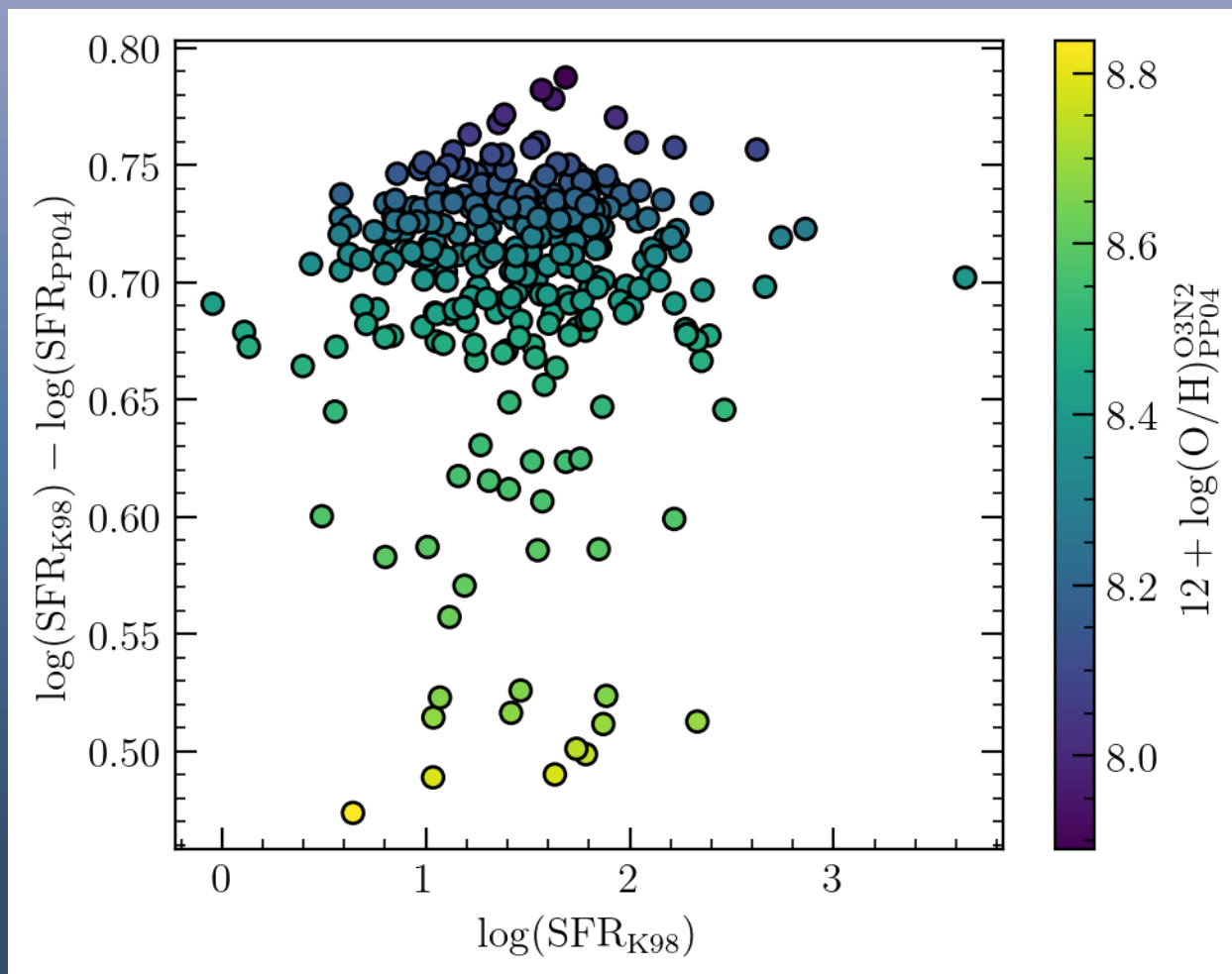
Salim, S., Lee, J. C., Ly, C., et al. 2014, ApJ, 797, 126, doi: 10.1088/0004-637X/797/2/126

Topping, M. W., Shapley, A. E., Sanders, R. L., et al. 2021, MNRAS, 506, 1237, doi: 10.1093/mnras/stab1793

Tremonti, C. A., Heckman, T. M., Kauffmann, G., et al. 2004, ApJ, 613, 898, doi: 10.1086/423264

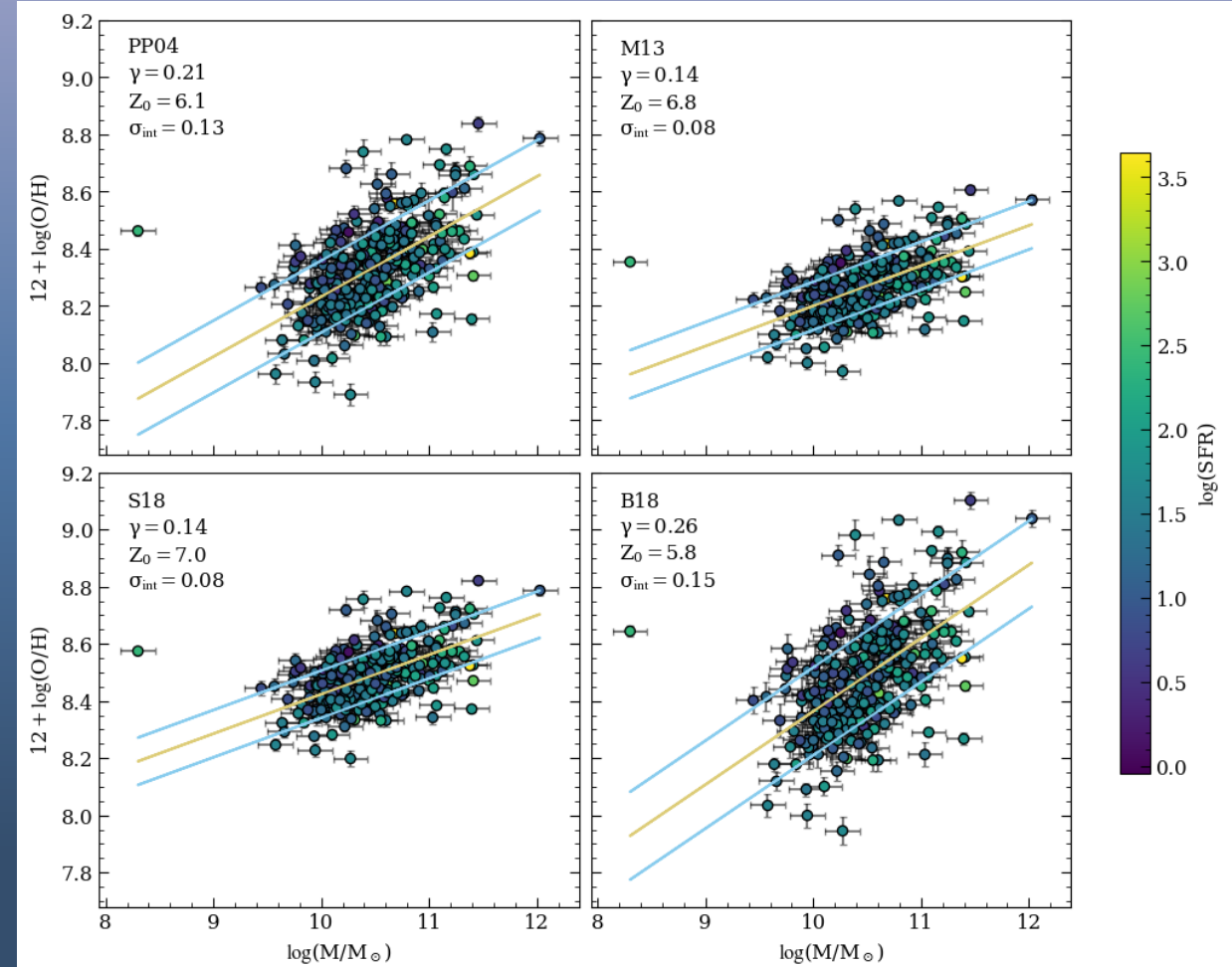
Backup Slides

Metallicity-Dependent SFR



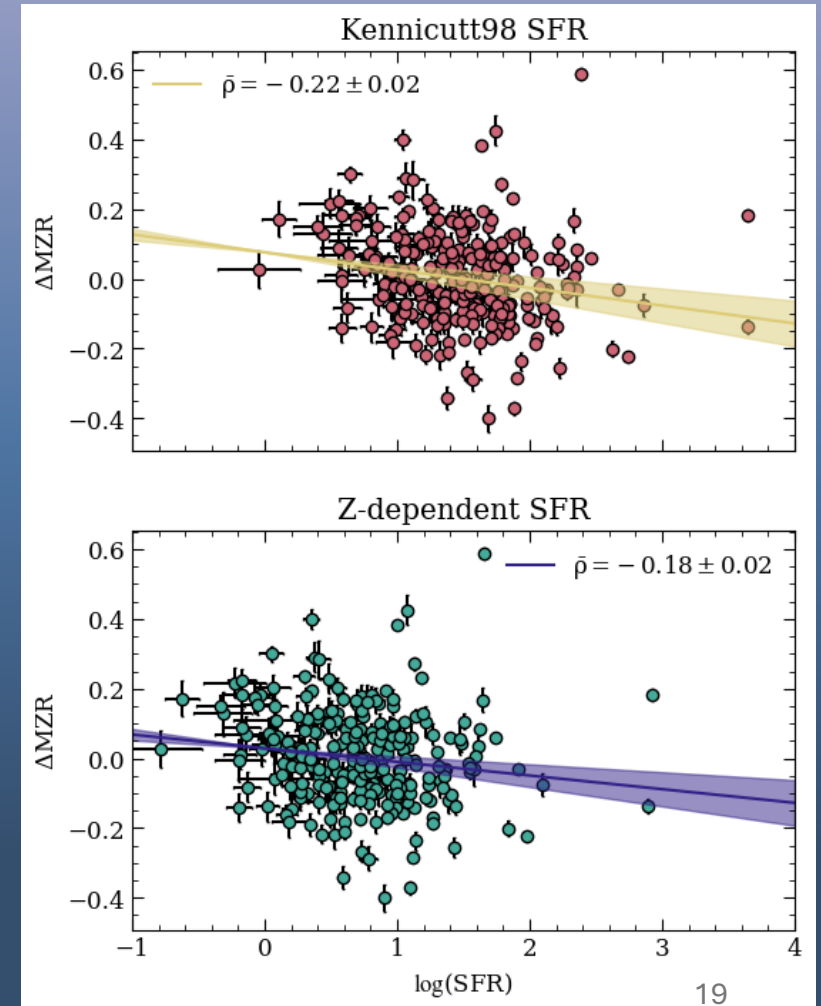
Mass-Metallicity Relations

- MZR shape depends on calibration.
- Slope varies by 0.12 dex
- Scatter varies by 0.07 dex
- Normalization varies by 1.2 dex

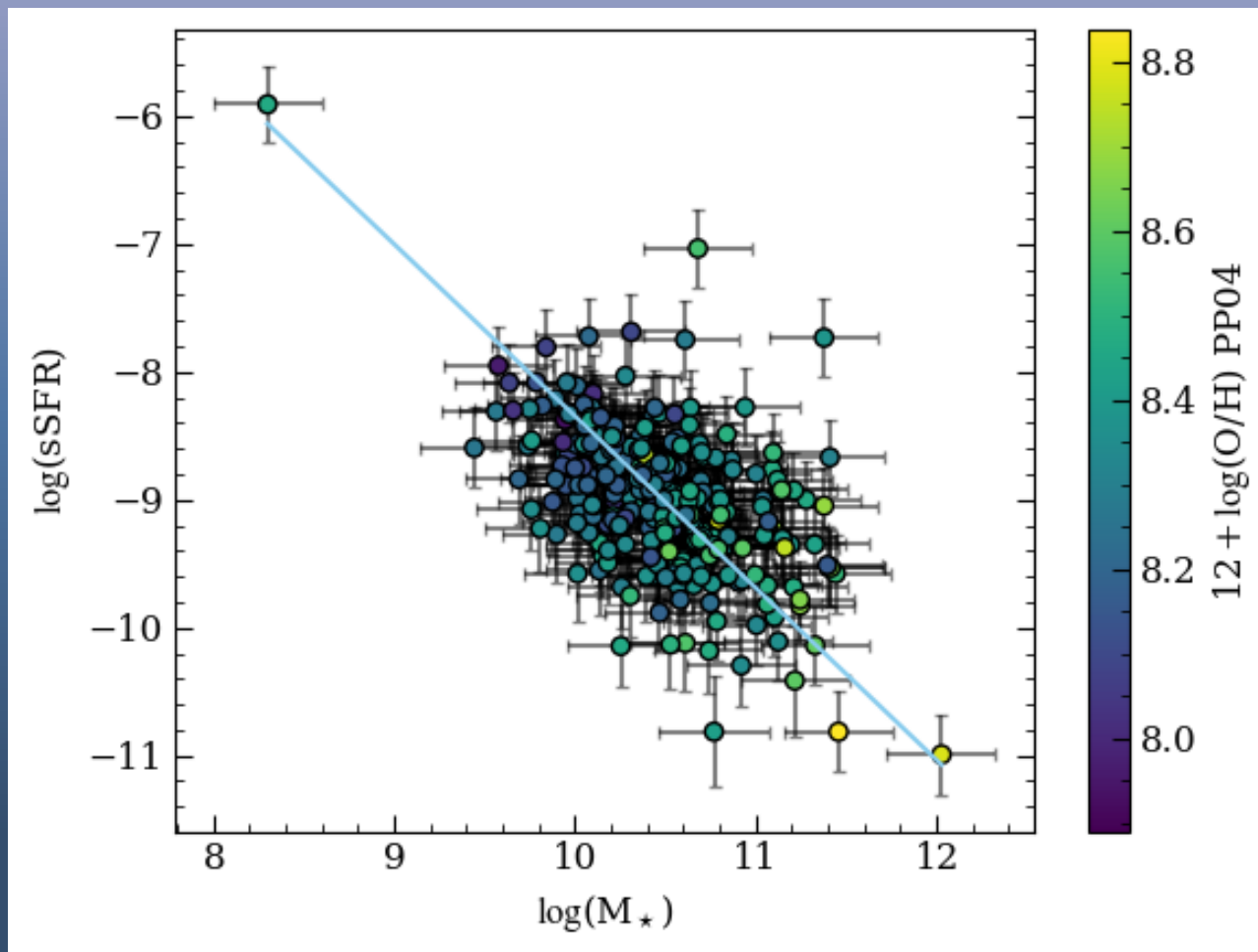


Non-Parametric Approach

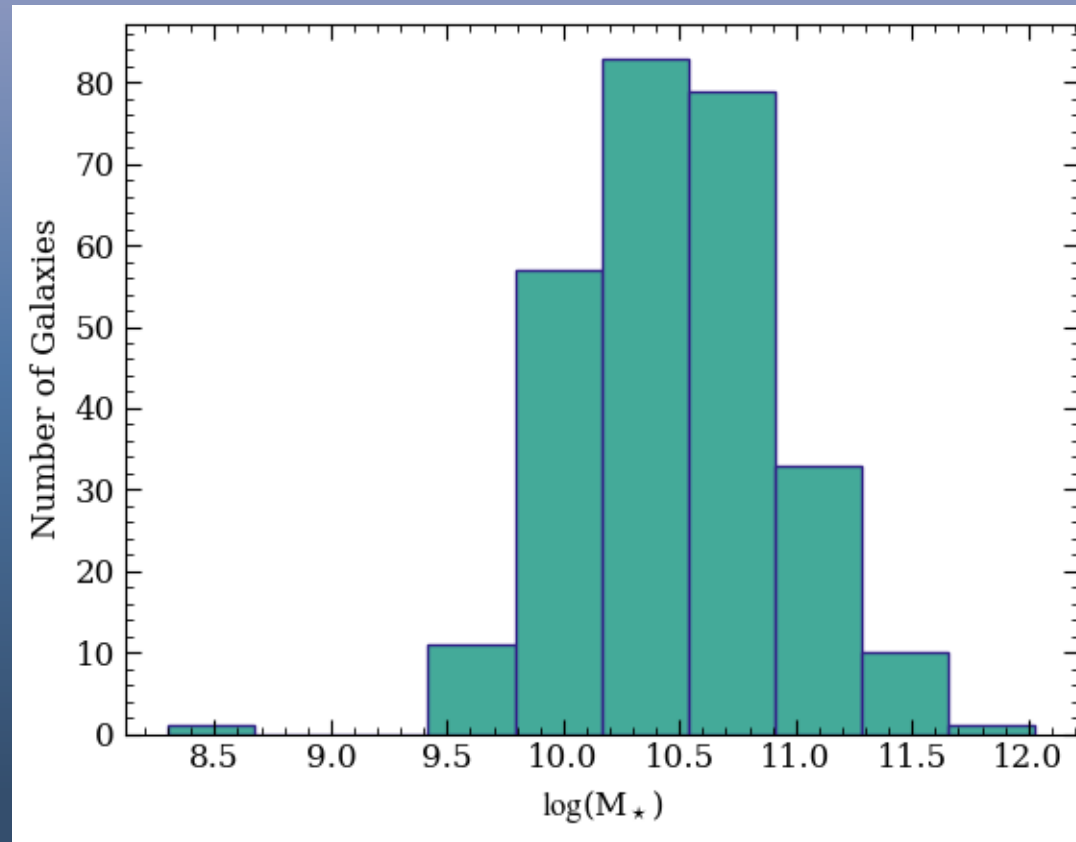
- Weak but significant correlation between MZR residual and absolute SFR.



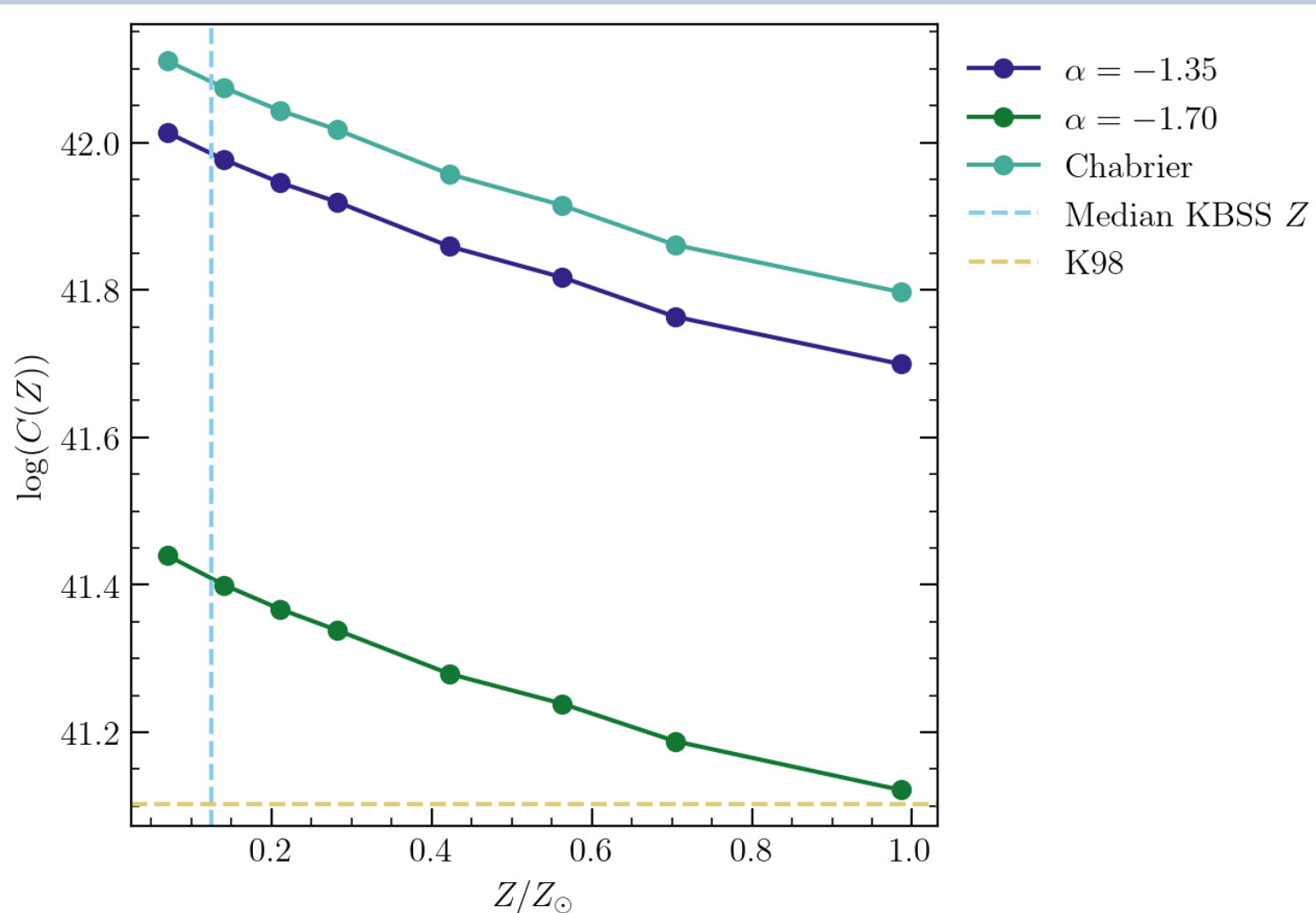
Mass-sSFR Relation



KBSS Galaxy Properties



Conversion factors with different IMF



Star Forming Main Sequence

