Properties of Local Galaxies and Scaling Relations

Renbin Yan
(University of Kentucky)

The Data Landscape

- Large area imaging Surveys:
  - GALEX, SDSS, 2MASS, UKIDSS, WISE, ALFALFA, (ROSAT All-Sky, FIRST, NVSS).
- Large single-aperture spectroscopic surveys of nearby galaxies:
  - SDSS, 2dF, GAMA
- Integral Field Spectroscopic surveys of nearby galaxies:
  - SAURON, ATLAS3D, DiskMass, VENGA, MASSIVE, CALIFA, SAMI, and MaNGA.

How to measure global quantity?

- Integrated Photometry: Petrosian, Sersic, B+D fitting
- For any quantity that requires spectroscopy, we actually don’t have large samples with global measurements available.
  - Slit and single-fiber spectroscopy are biased
  - Drift-scan spectroscopy or IFS are our only ways.

How a global quantity should be represented when the quantity has spatial gradient in a galaxy?

- Using the integrated value
- The value at Re, or other characteristic place.
- Weighted average

Difficulty at getting the Global Value

- Example 1: Color
  Color reflects the SFH (and metallicity).
  The global color derived from integrated magnitudes is simply is the average SFH of all components.

$$\frac{F_{u1} + F_{u2}}{F_{r1} + F_{r2}}$$

However, if there is spatial gradient in dust extinction, the global color becomes a weighted average of the SFH, weighted by the attenuated flux.

$$\frac{F_{u1}e^{-\tau_1} + F_{u2}e^{-\tau_2}}{F_{r1}e^{-\tau_1} + F_{r2}e^{-\tau_2}}$$

Difficulty at Getting the Global Value

- Example 2: Gas Metallicity in a star-forming galaxy

  Global [O/H] measured in the integrated spectrum is the average [O/H] weighted by the intensity of star formation in each region.

Scaling Relations

- physics of SF: Kennicutt-Schmidt relation
- SF history:
  - color- luminosity relation
  - SFR - mass relation
  - mass - metallicity relation
  - mass - metallicity - SFR relation
  - stellar mass - halo mass relation
- BH formation: M- sigma relation
- galactic structure: Luminosity - Kinematics (- size) Relation (Tully-Fisher, Faber-Jackson, Fundamental Plane, mass-size)

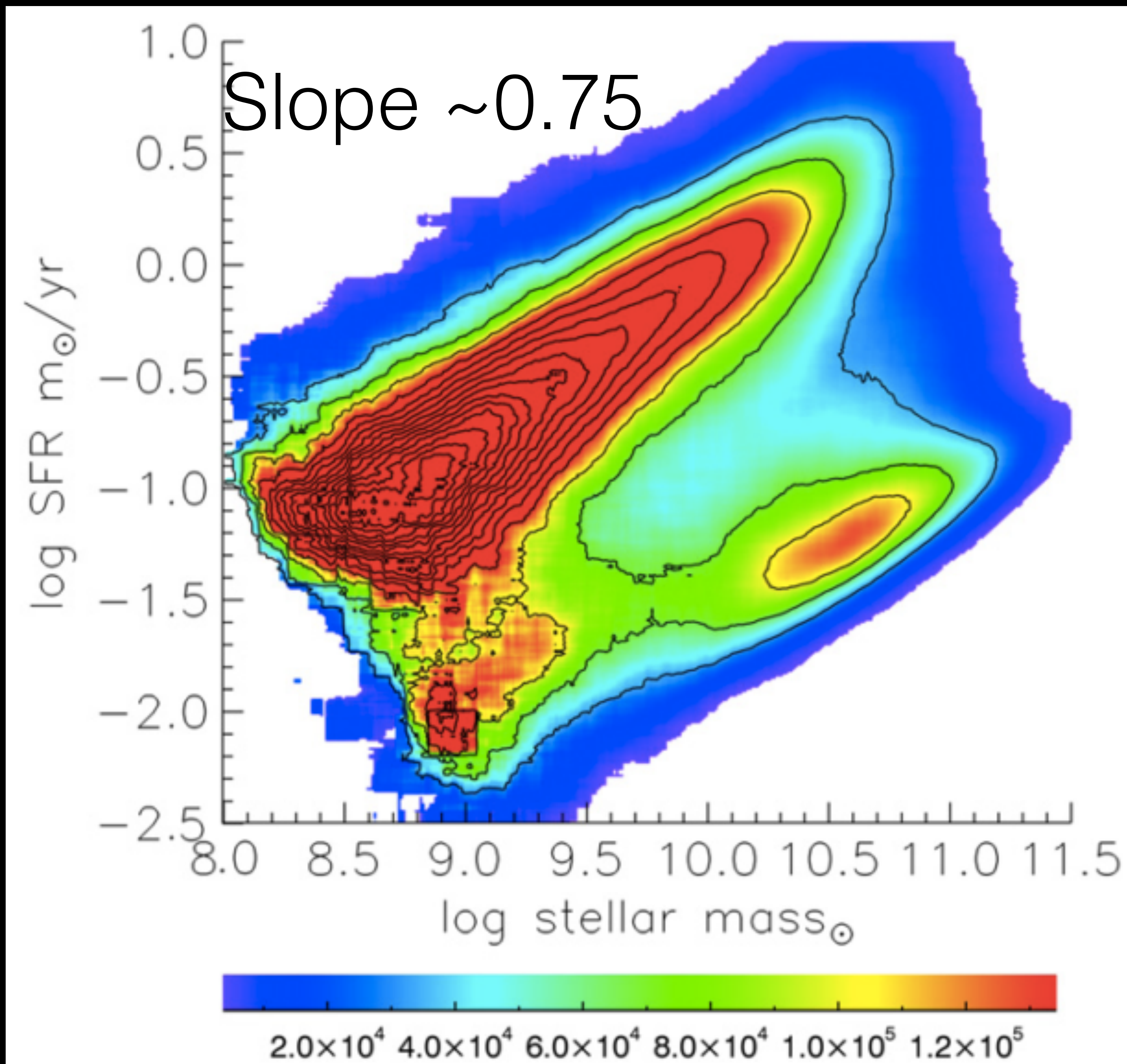
Measurement error vs. intrinsic scatter

useful for discovering
secondary dependence

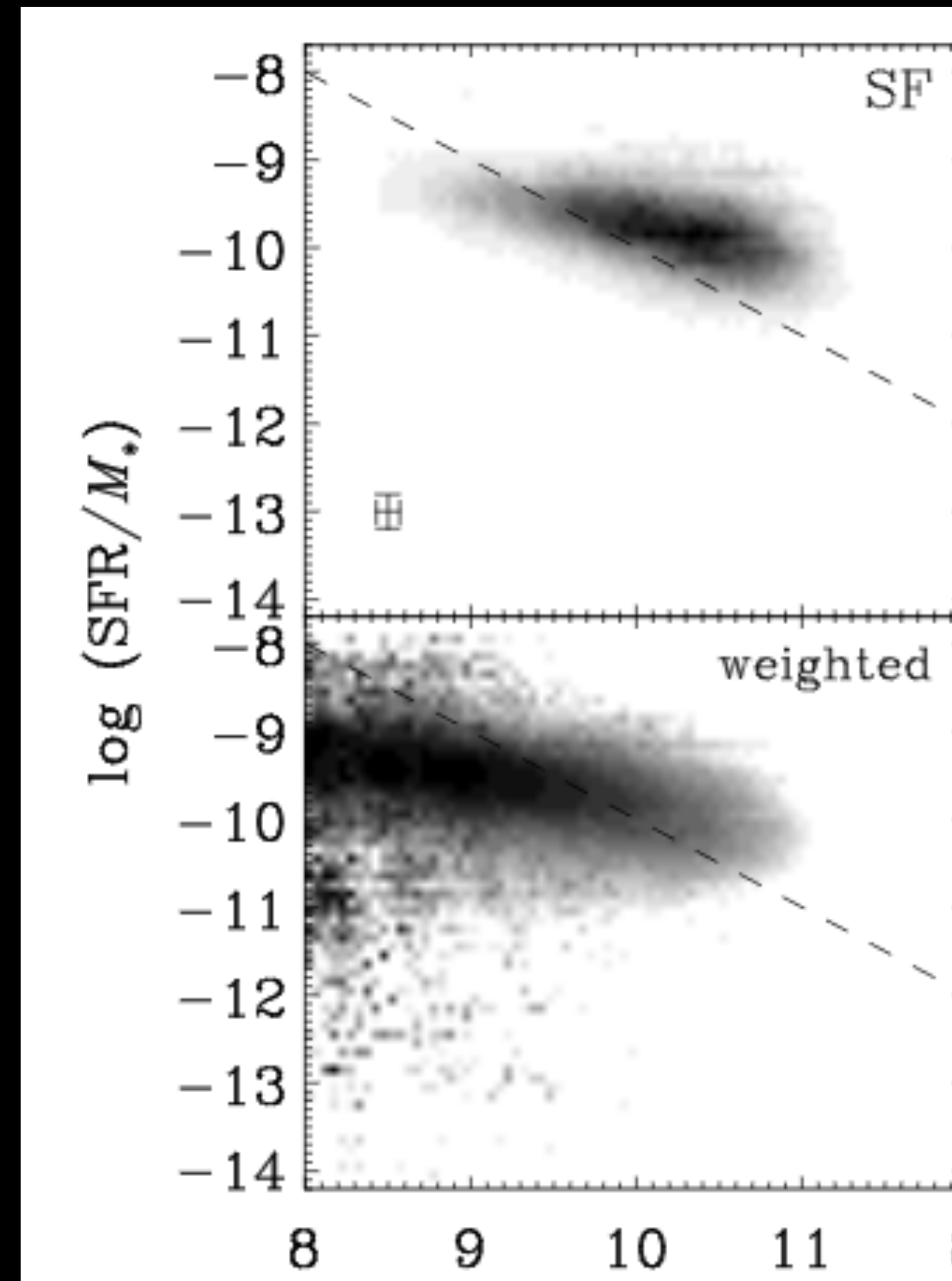
Random error vs. Systematic error

Model-dependent
Empirical-Calibration-dependent
Not necessarily a normalization offset

SFR - M_{star} relation



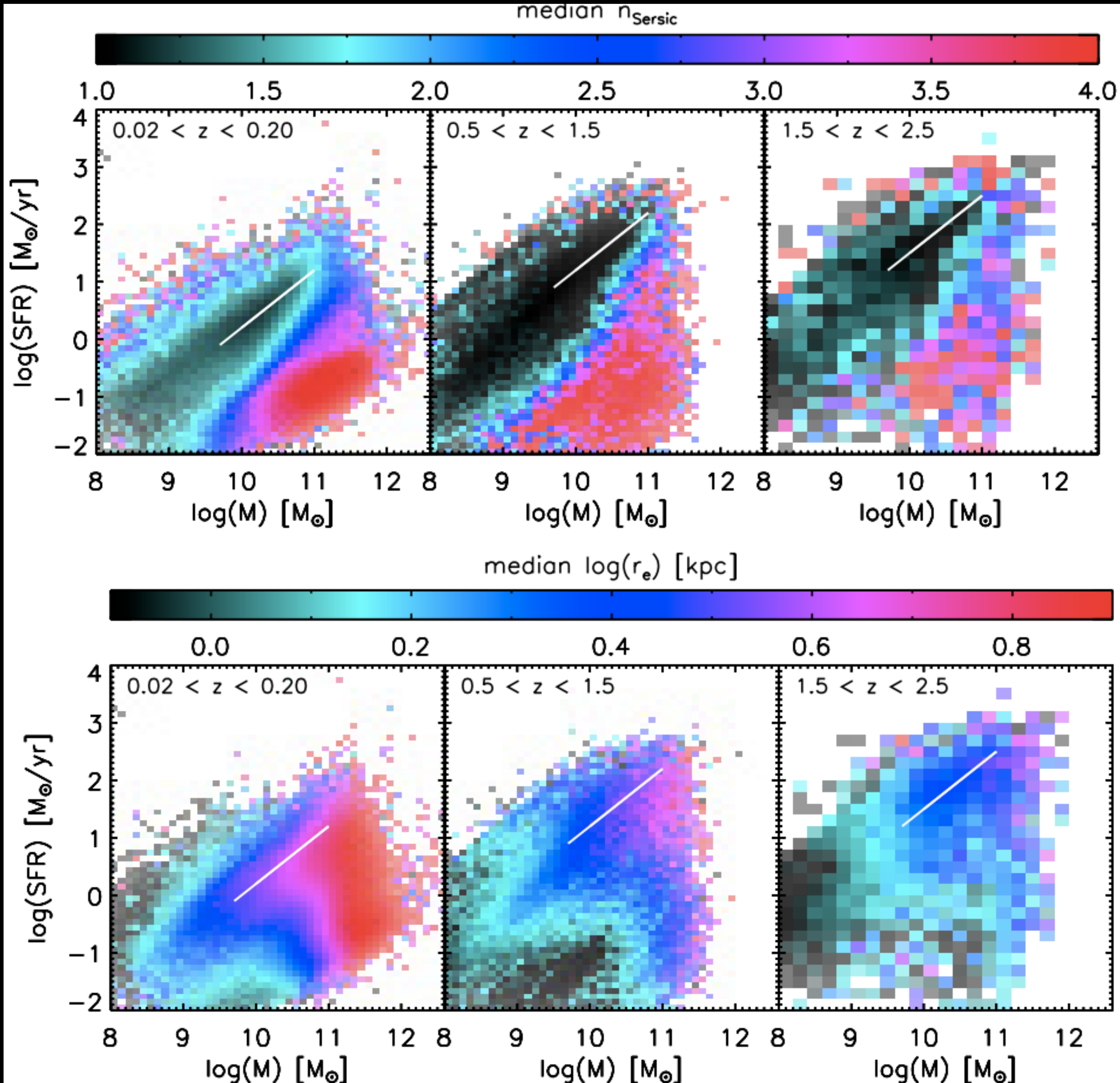
Renzini & Peng (2015)



Salim et al. (2007)

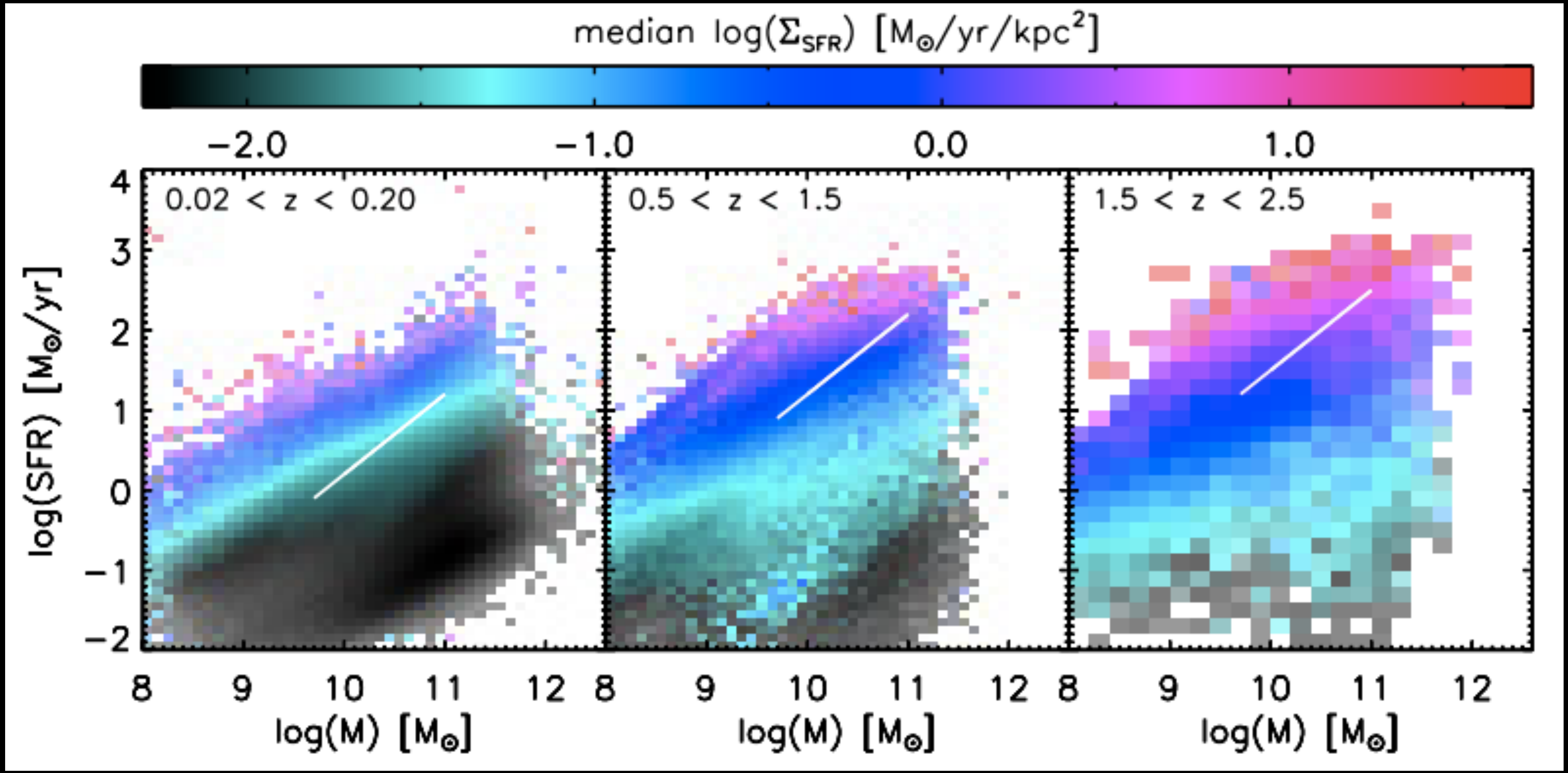
And Brinchman+ (2004), Salim+ (2005), Salim & Lee (2012), Noeske et al. (2007), Elbaz+ (2007), Daddi+ (2007), Wuyts+(2011)

Structure SF main sequence



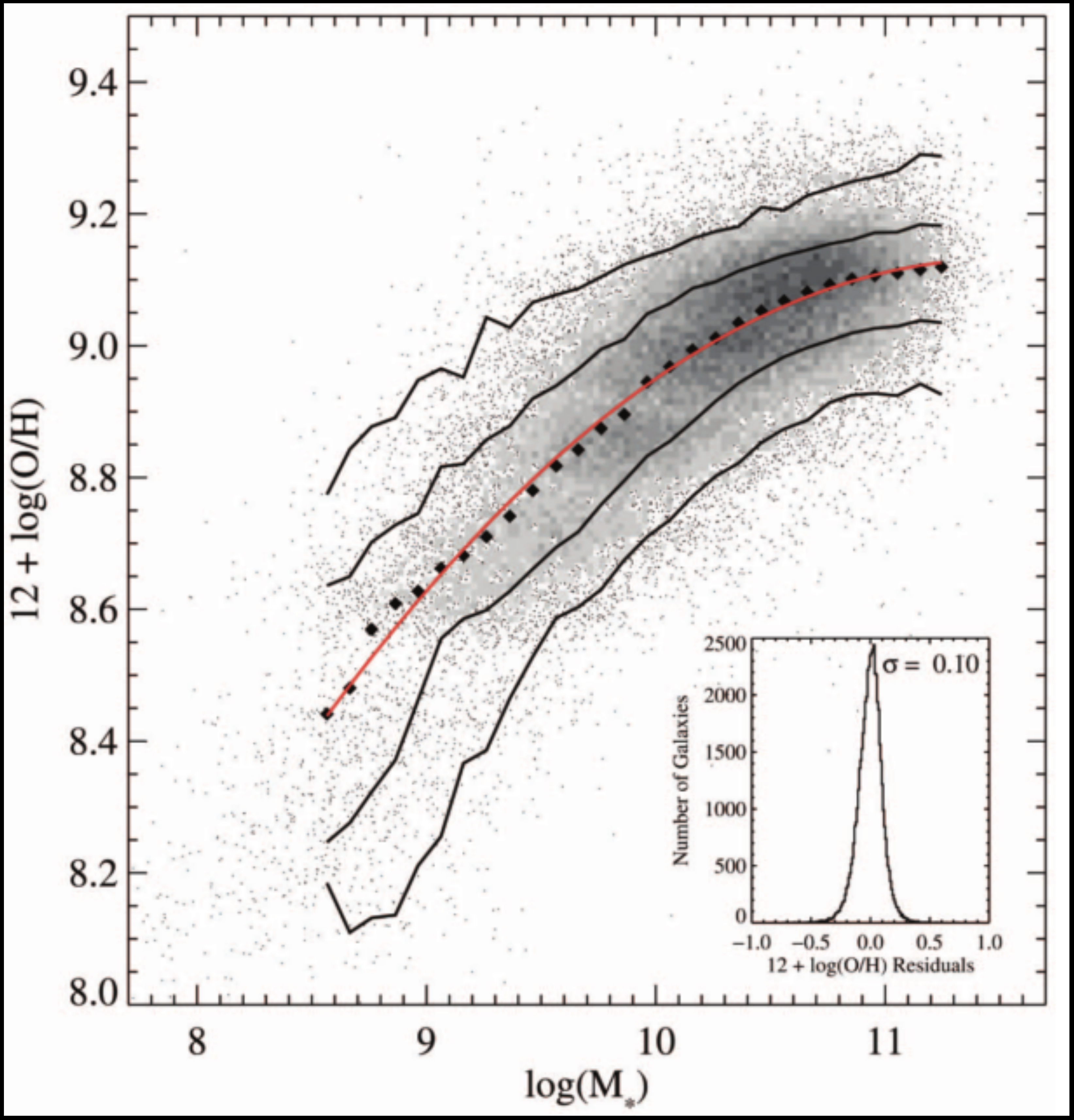
Slope~1

Wuyts et al. (2011



Wuyts et al. (2011)

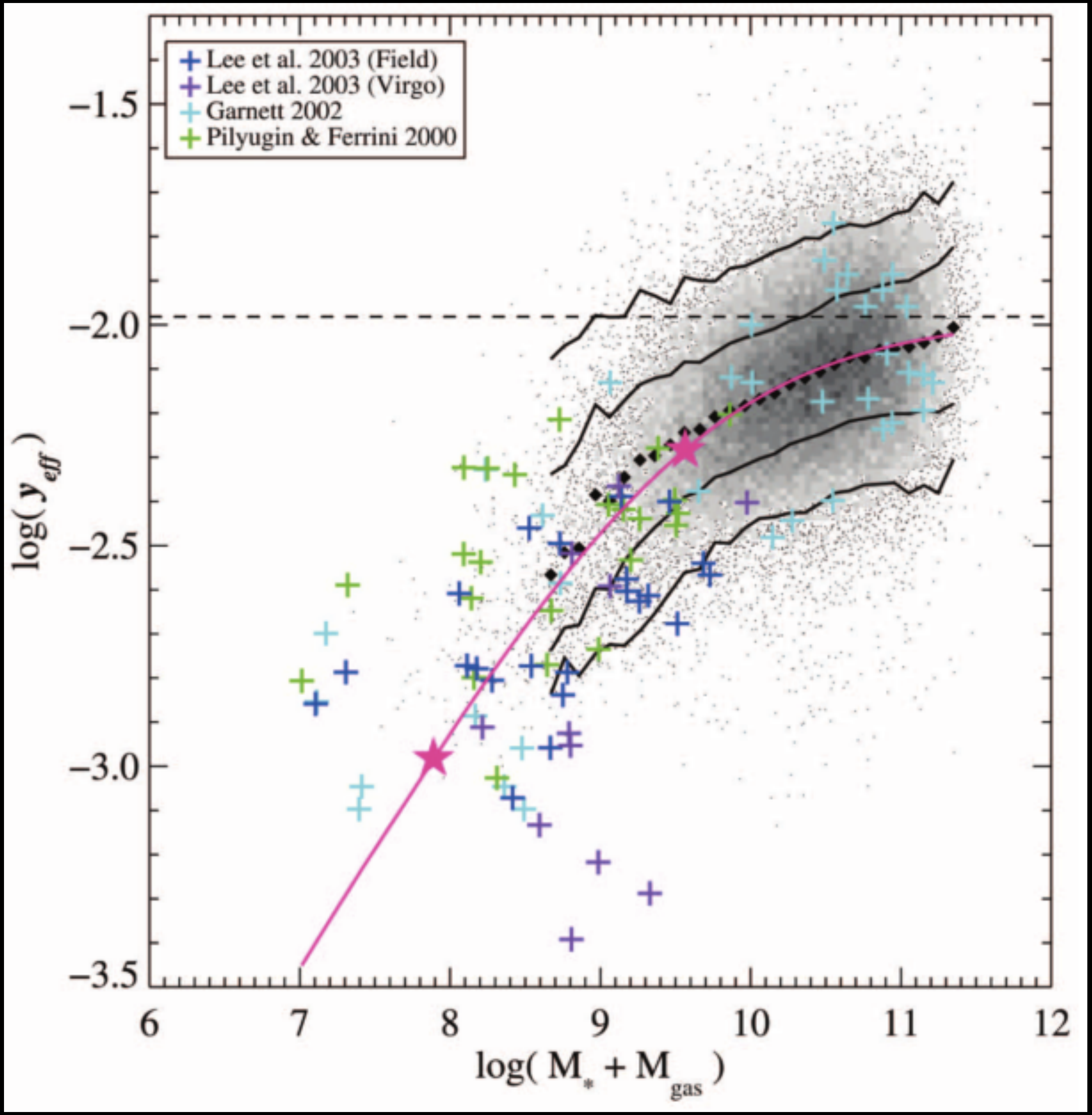
Mass-Metallicity Relation



The scatter is about twice the measurement error.

Tremonti et al. (2004)

Effective Yield vs. Baryonic Mass



Close-box model:

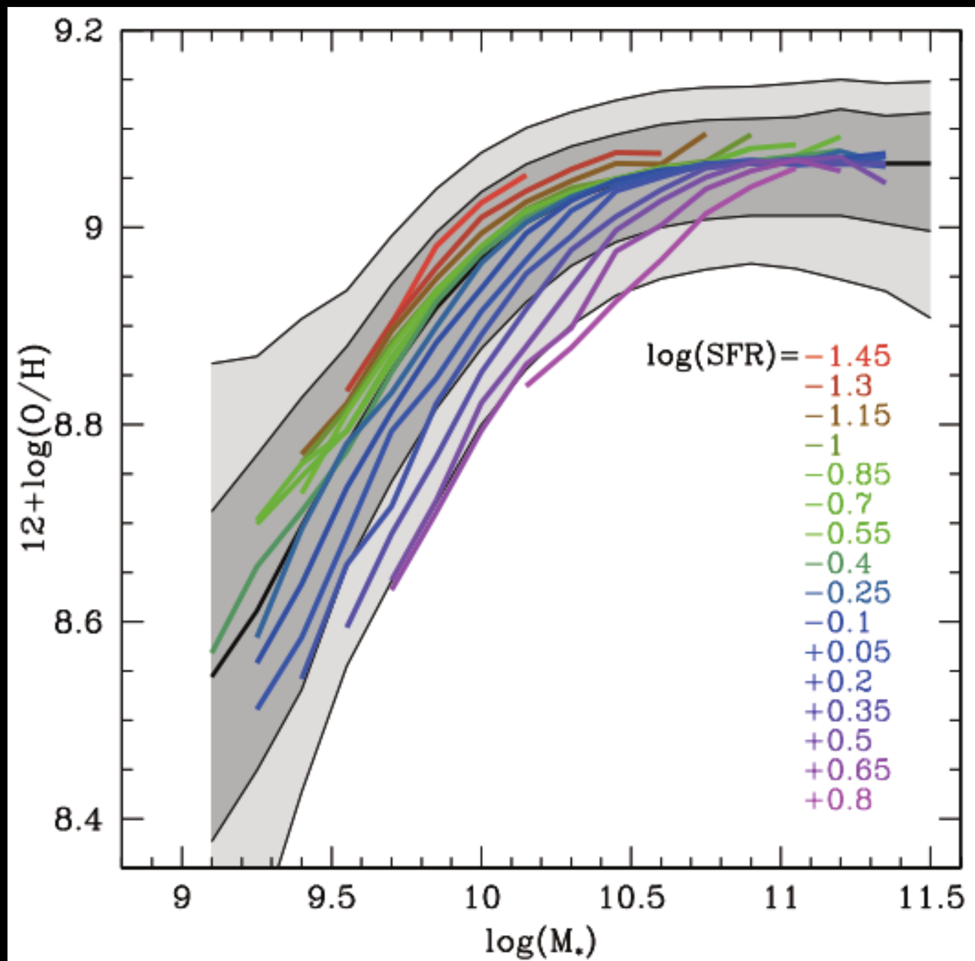
$$Z = y \ln(\mu_{\rm gas}^{-1})$$

Define:

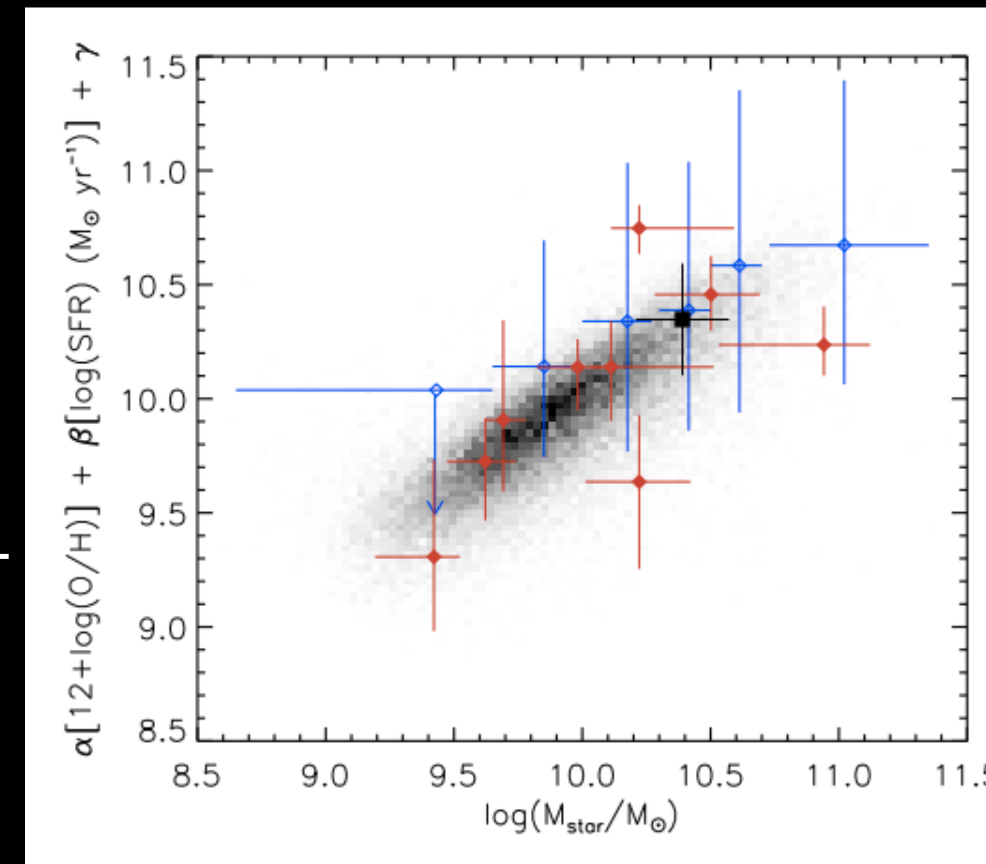
$$y_{\rm eff} = \frac{Z}{\ln(\mu_{\rm gas}^{-1})}$$

Tremonti et al. (2004)

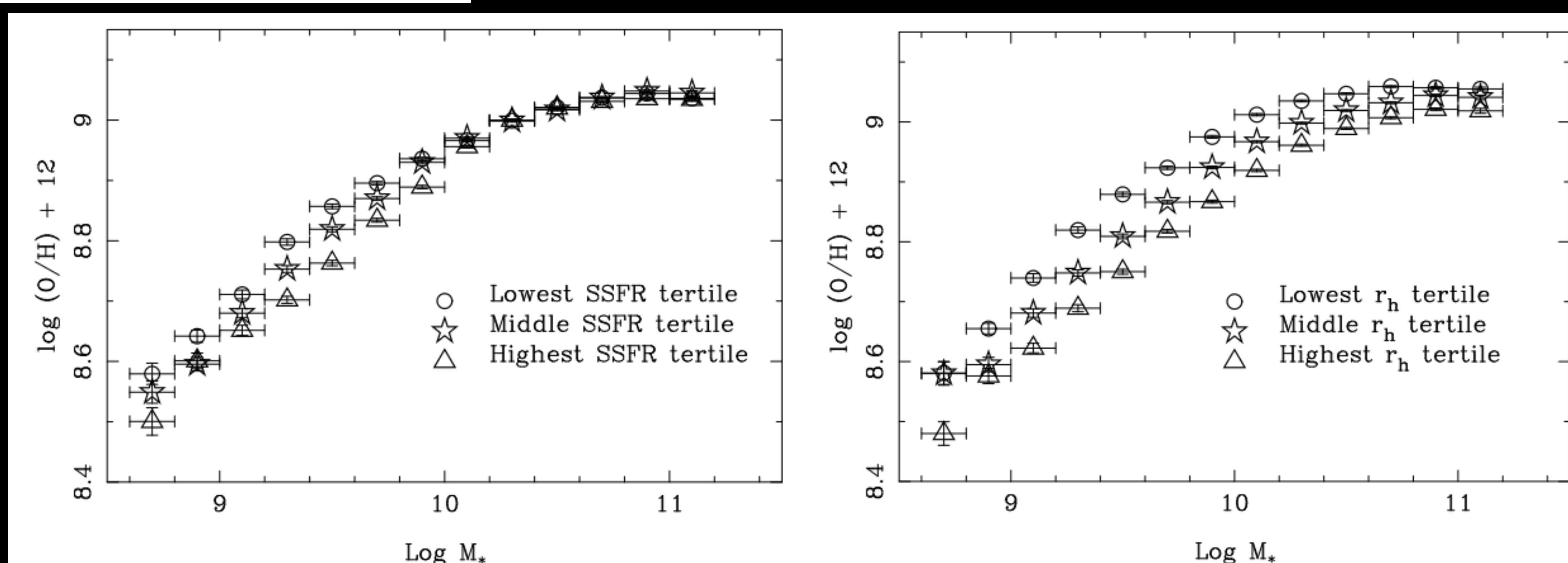
Mass-Metallicity-SFR Relation



Mannucci+ (2010)

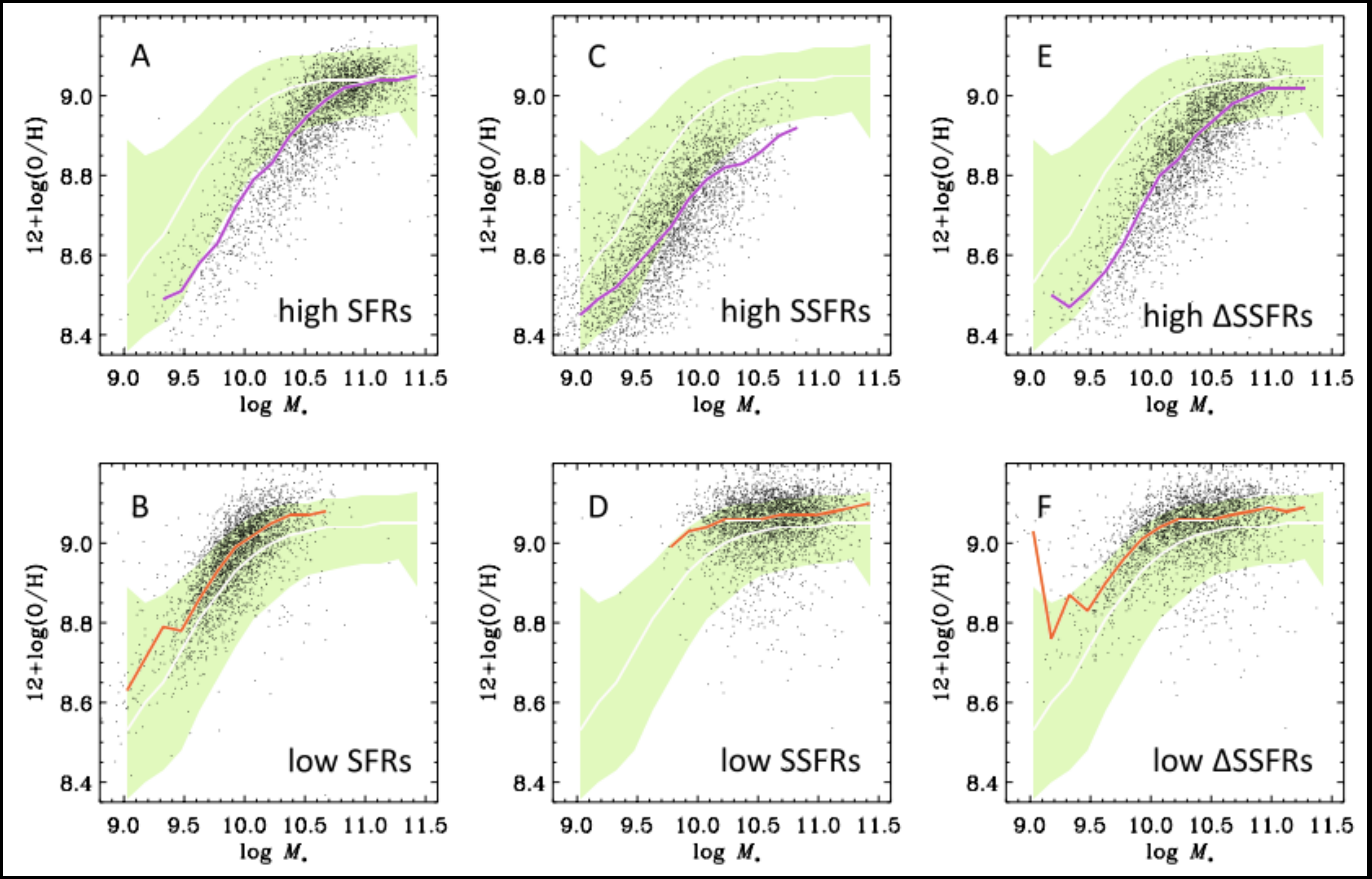


Lara-López+ (2010)



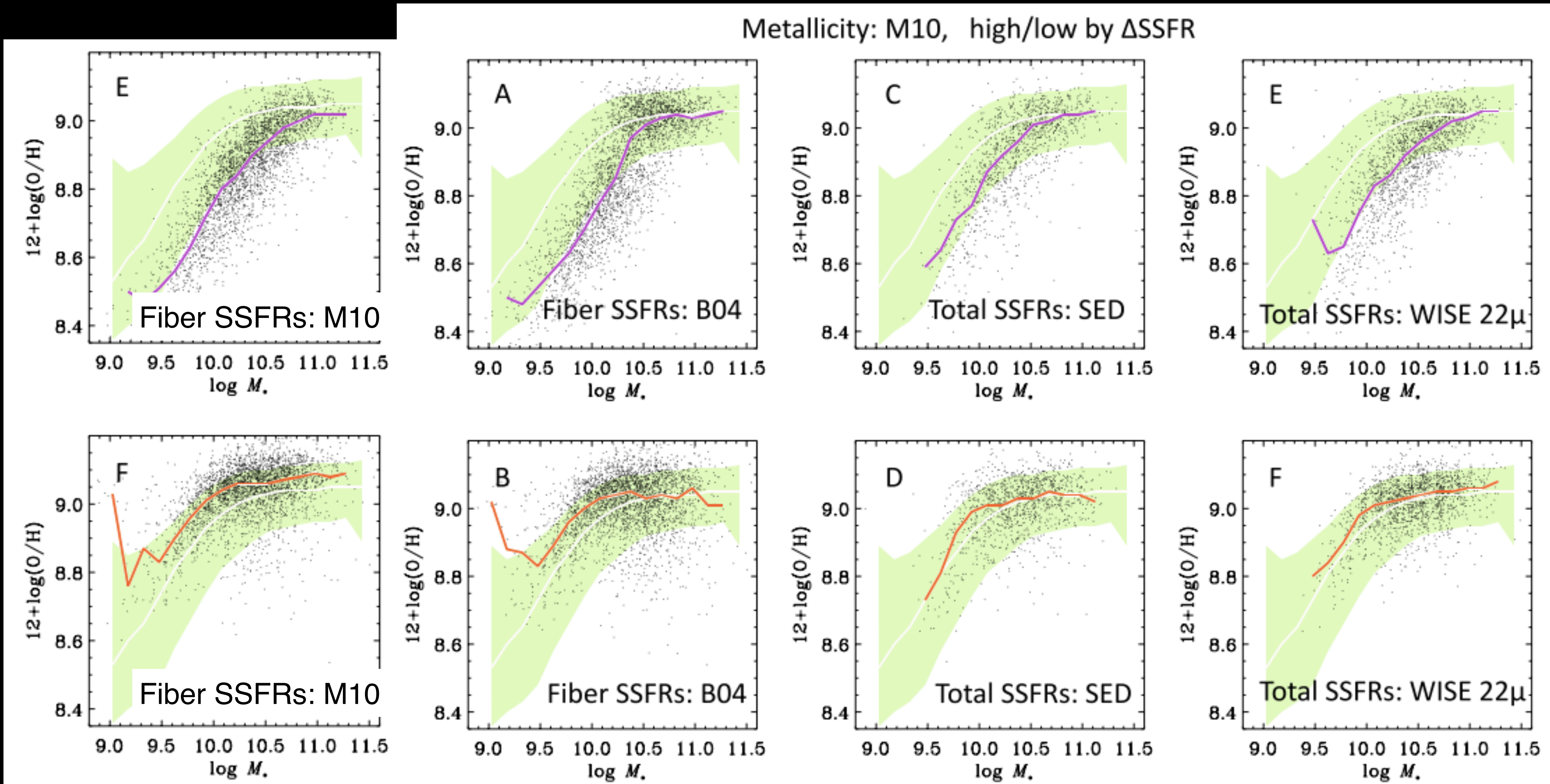
Ellison+ (2008)

What secondary parameter to use matters



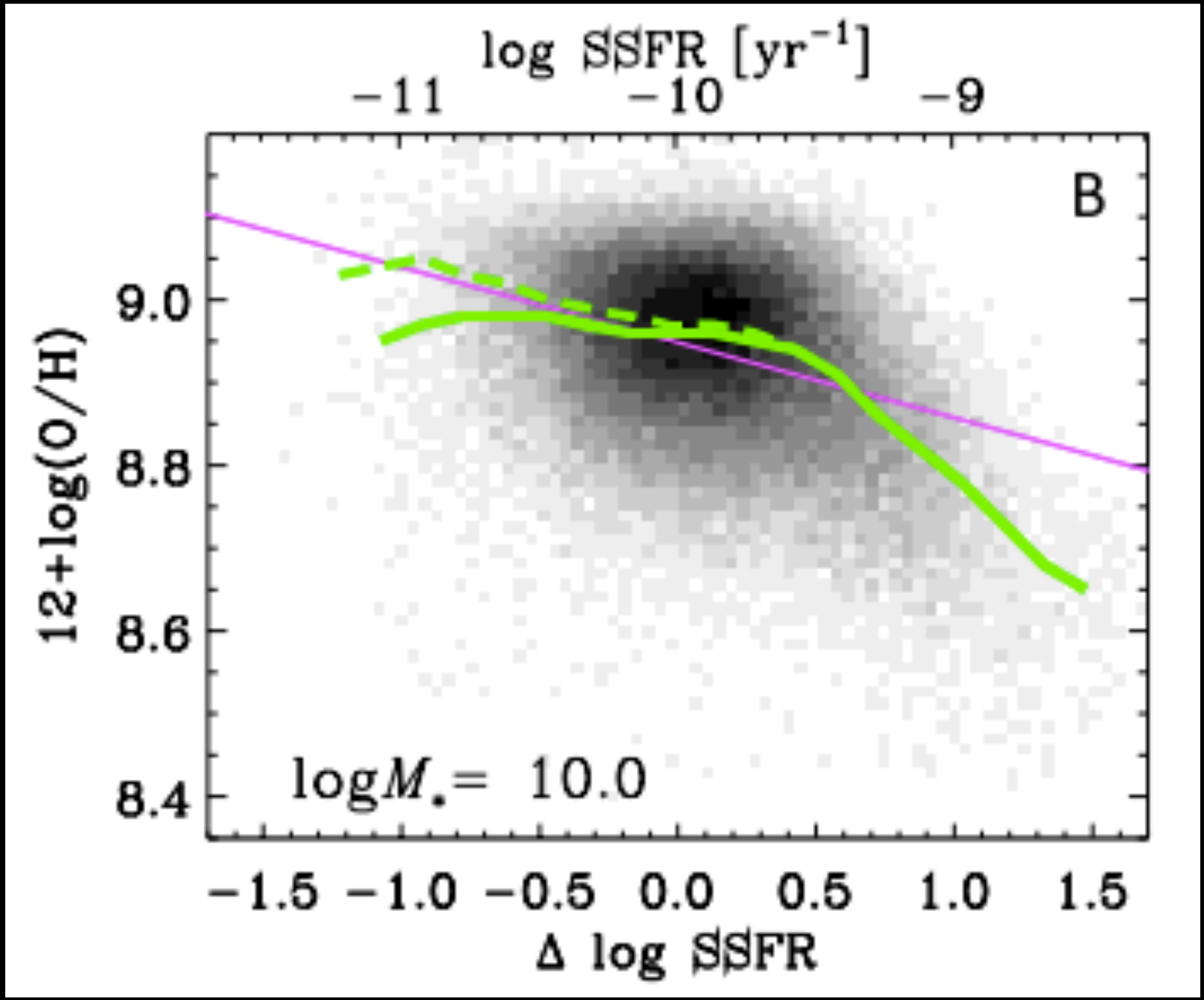
Salim et al. (2014)

SFR indicator matters



- Both fiber and total sSFR show the dependence.
- Different methods for SFR affect the strength of the

S/N ratio cuts on lines matters!!!



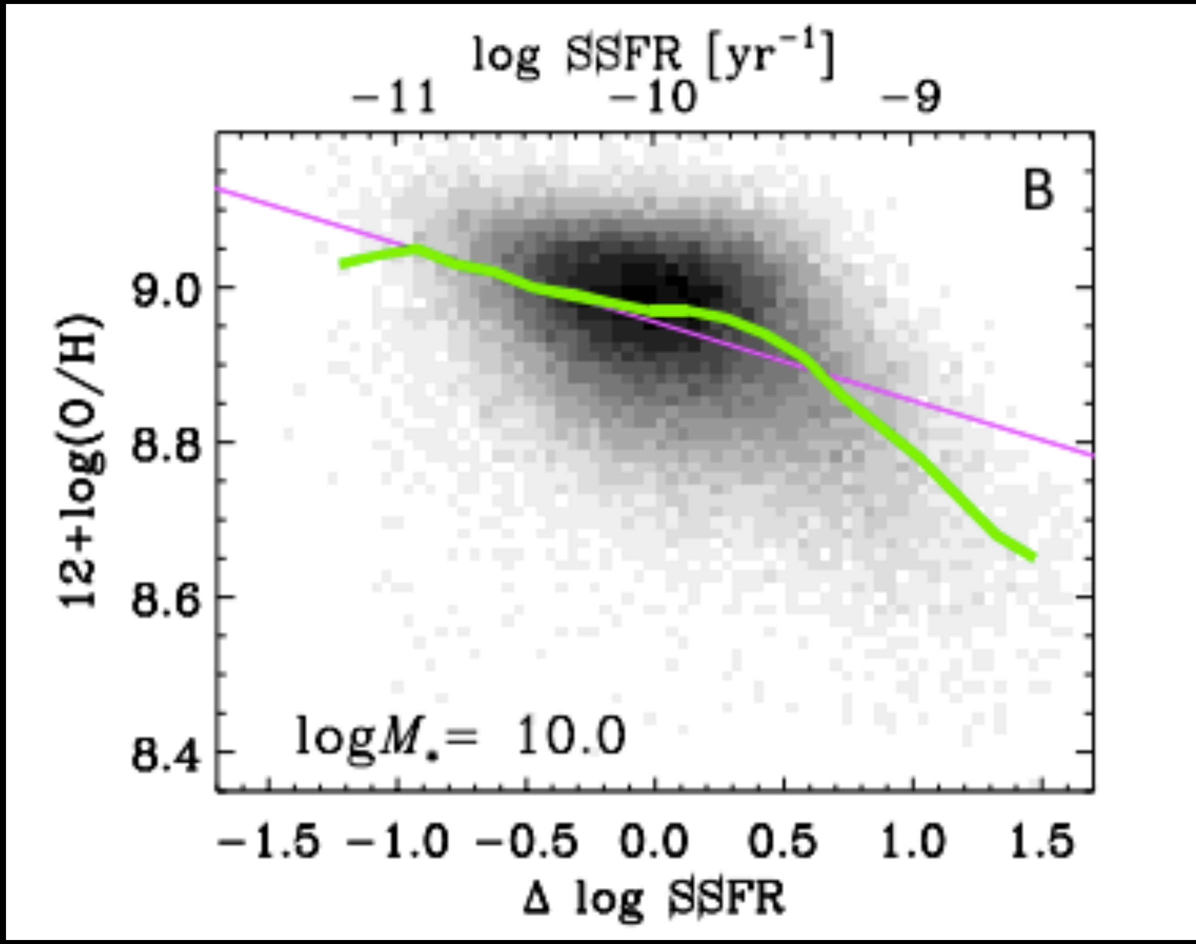
- Dashed: S/N (Ha) > 25
- Solid: S/N (Ha)> 25 and S/N(Hb, [OIII], [NII]) > 5.5, 4.5,

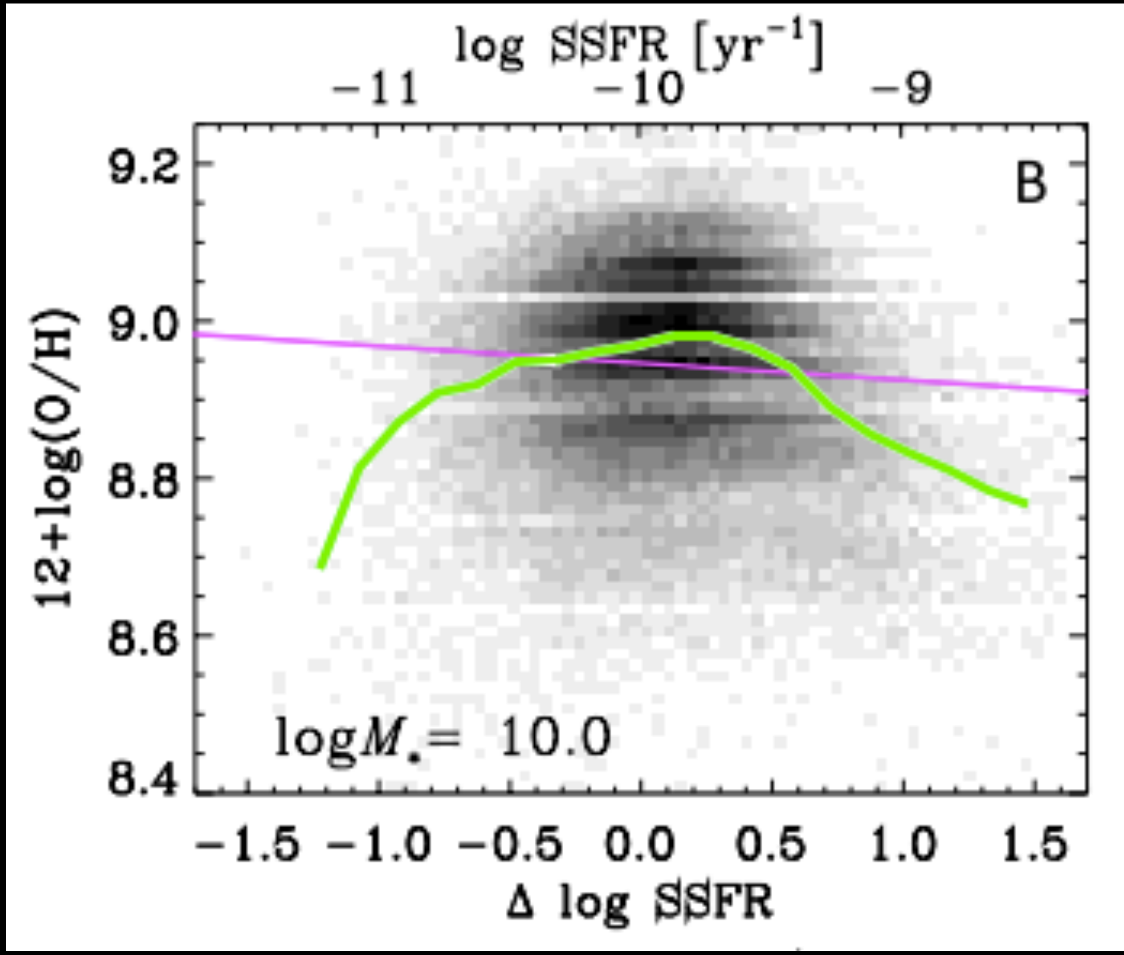
Metallicity Estimator Matters!

[O/H] measurement based on

Mannucci+ 2010 vs. Tremonti+ 2004

Average of R23 and N2 | Bayesian Method





Plots from Salim+2014

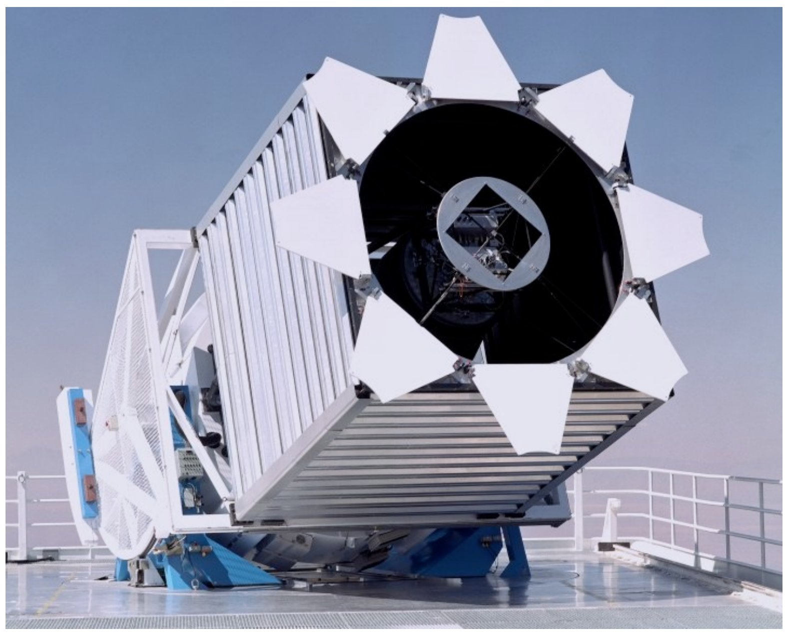
- Different metallicity mestimators give different dependence strength.

Intrinsic Scatter not fully explained

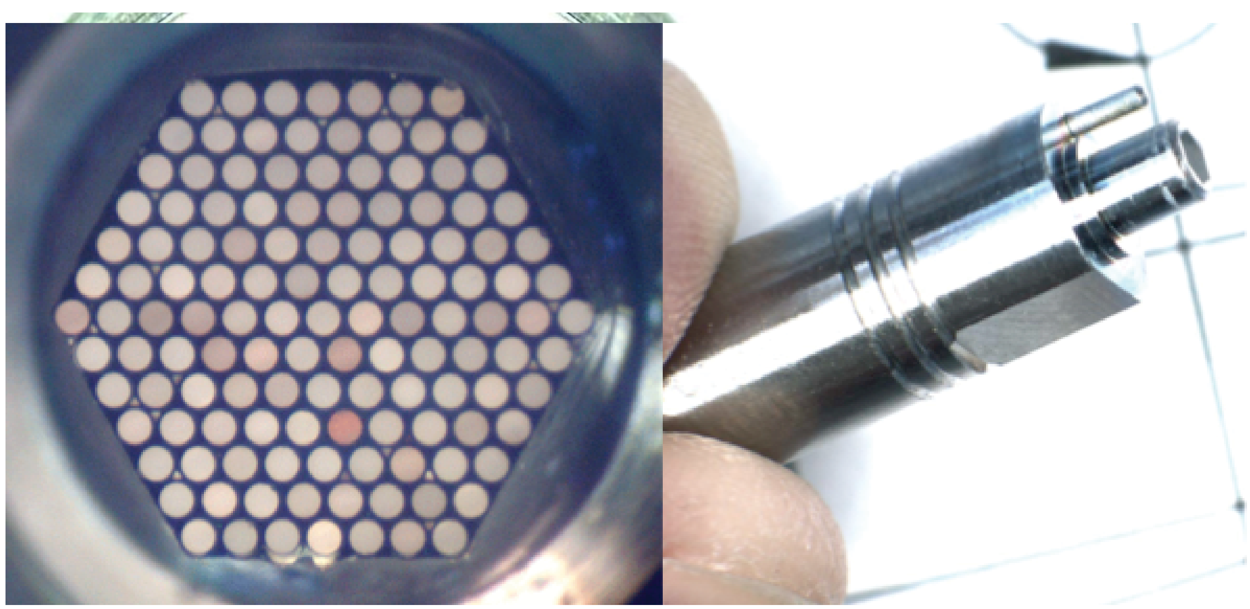
- Taking into account of the SFR dependence only reduces the scatter from 0.1 dex to 0.09 dex — very minor reduction. (Ellison+08, Pérez-Montero+13, Salim+15)
  Still much more than measurement noise.
- There is also tertiary dependence on galaxy size, but it does not reduce the scatter much either.

There is another thing!

SDSS-IV/MaNGA
Mapping Nearby Galaxies at APO

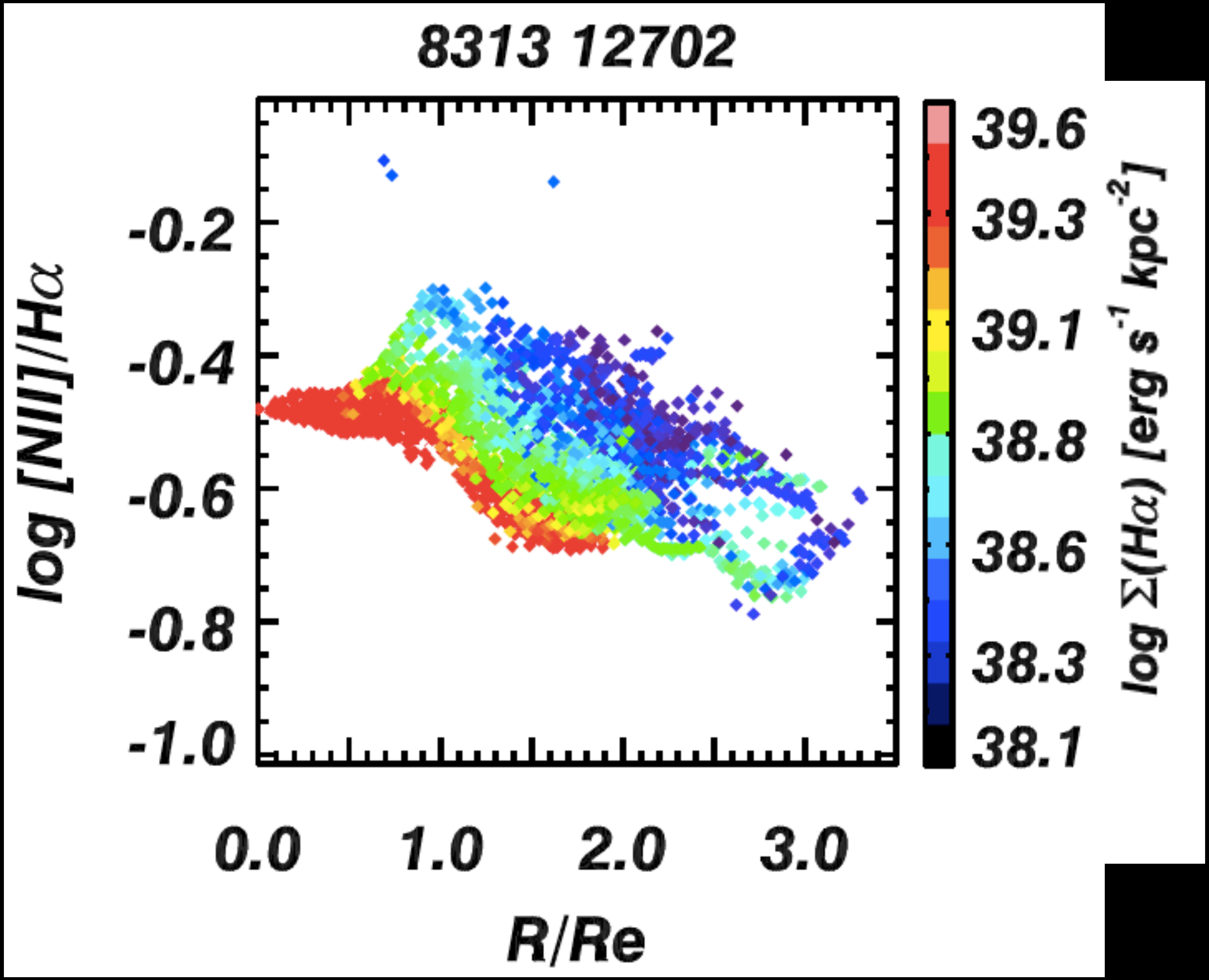


- Part of SDSS-IV
- Multi-object IFS: 17 galaxies per 7 sq. deg. pointing
- 10,000 galaxies in 6 years (by Summer 2020).
- Spatial resolution: 2.5” (1-2kpc);
  spectral resolution: 50-70 km/s (sigma), R~2000;
  spectral coverage: 3,630-10,300A.



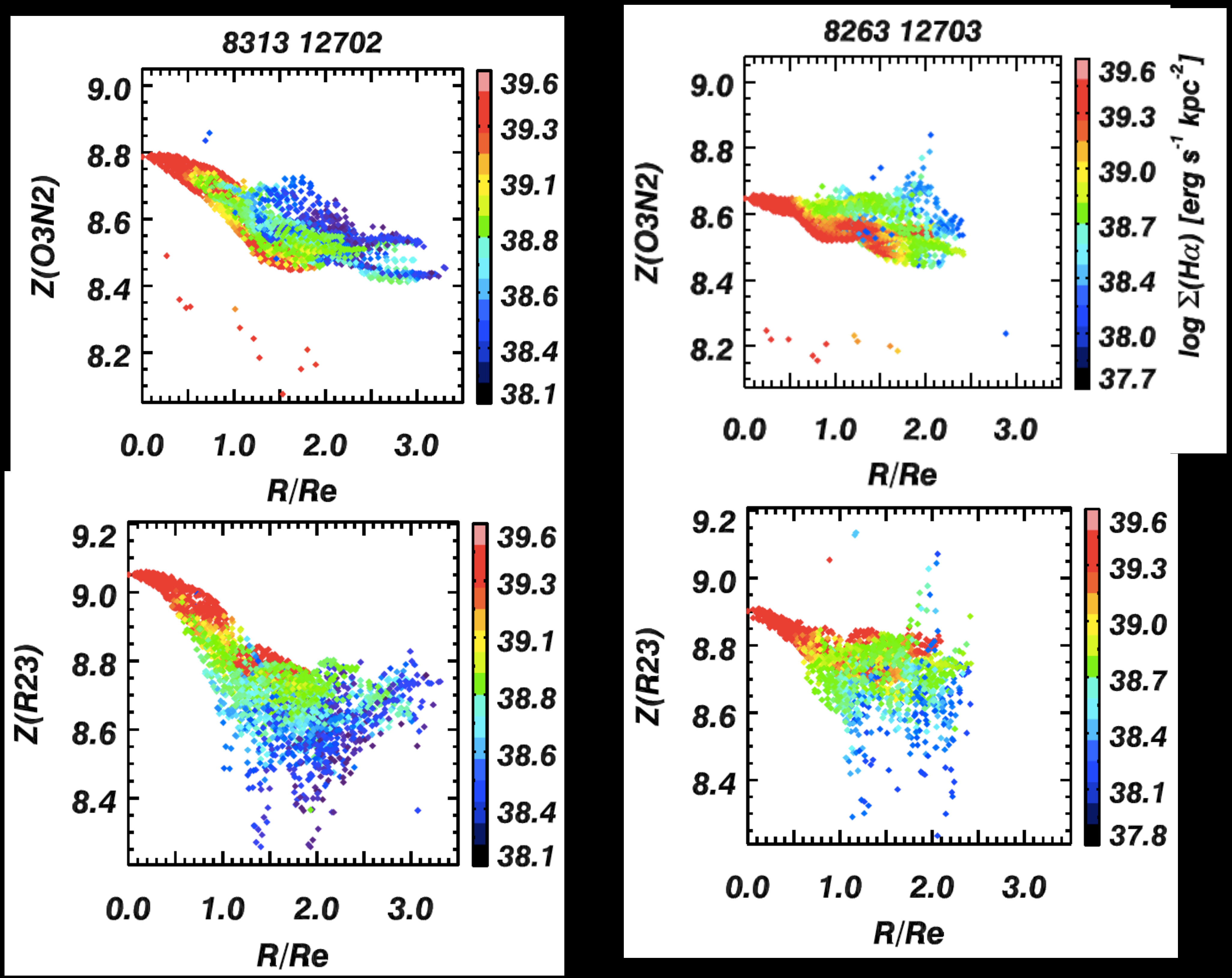
- Median S/N per A of 5.5 per fiber in r-band at 1.5Re with an average of 2.5 hour integration.
- Up to today (Apr 9, 2016), we have observed ~2500 unique galaxies!

Impact of Diffuse Ionized Gas



Zhang et al. in prep; see poster by Kai Zhang

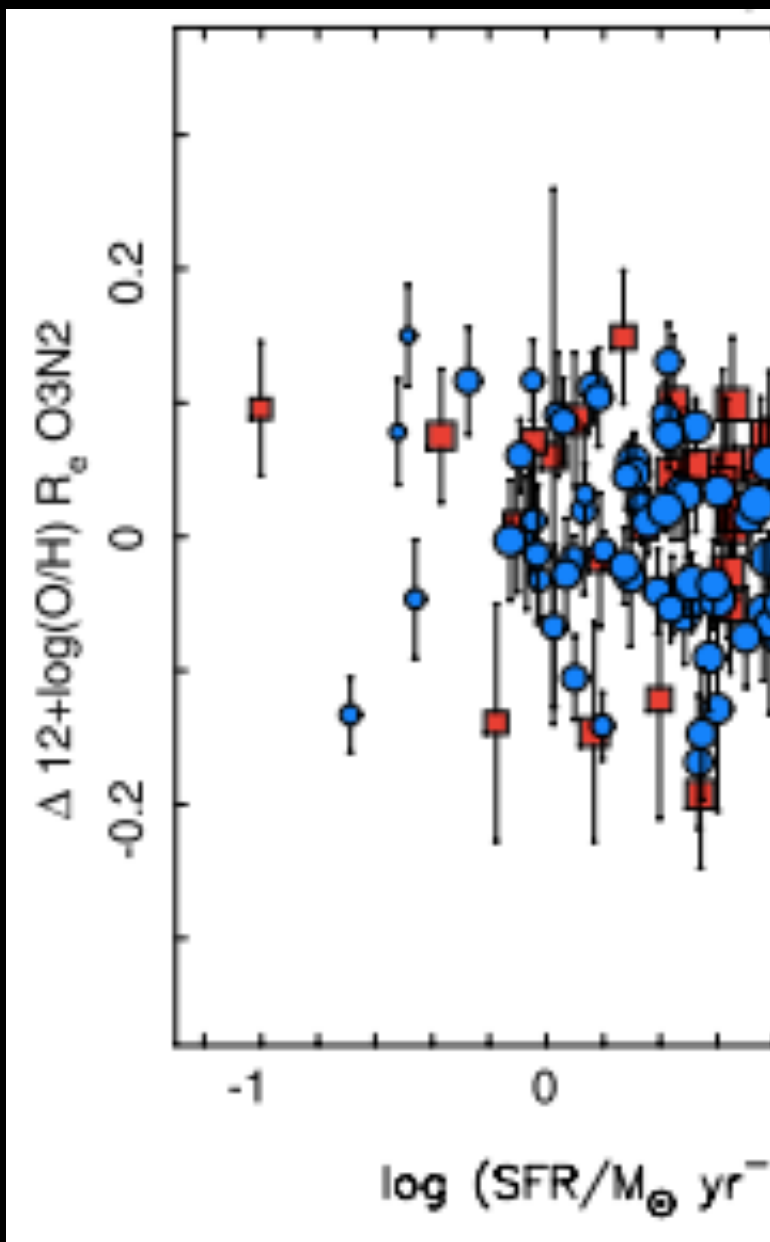
Different metallicity estimators are affected differently.



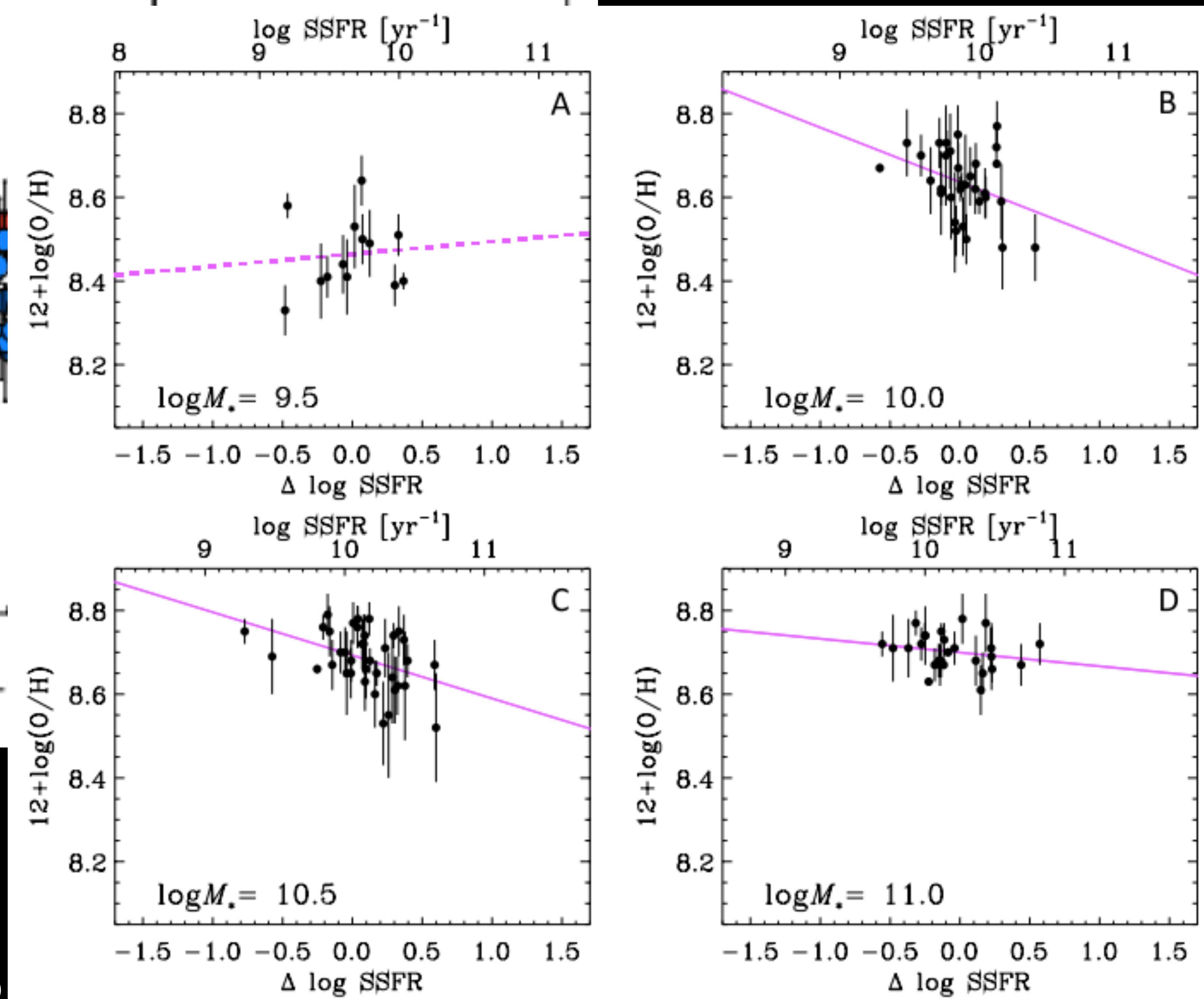
Summary

- Global measurements are difficult to make — we need to treat them carefully.
- To make progress, we need to understand ALL systematic errors in the measurements, related to sample selection, S/N cuts, empirical calibration, model assumptions
- Diffuse Ionized Gas has significant impact on metallicity measurements.

Aperture Effect



Sanchez+13



Salim+15