The Mass—Metallicity Relation in SDSS Using Electron Temperature Measurements

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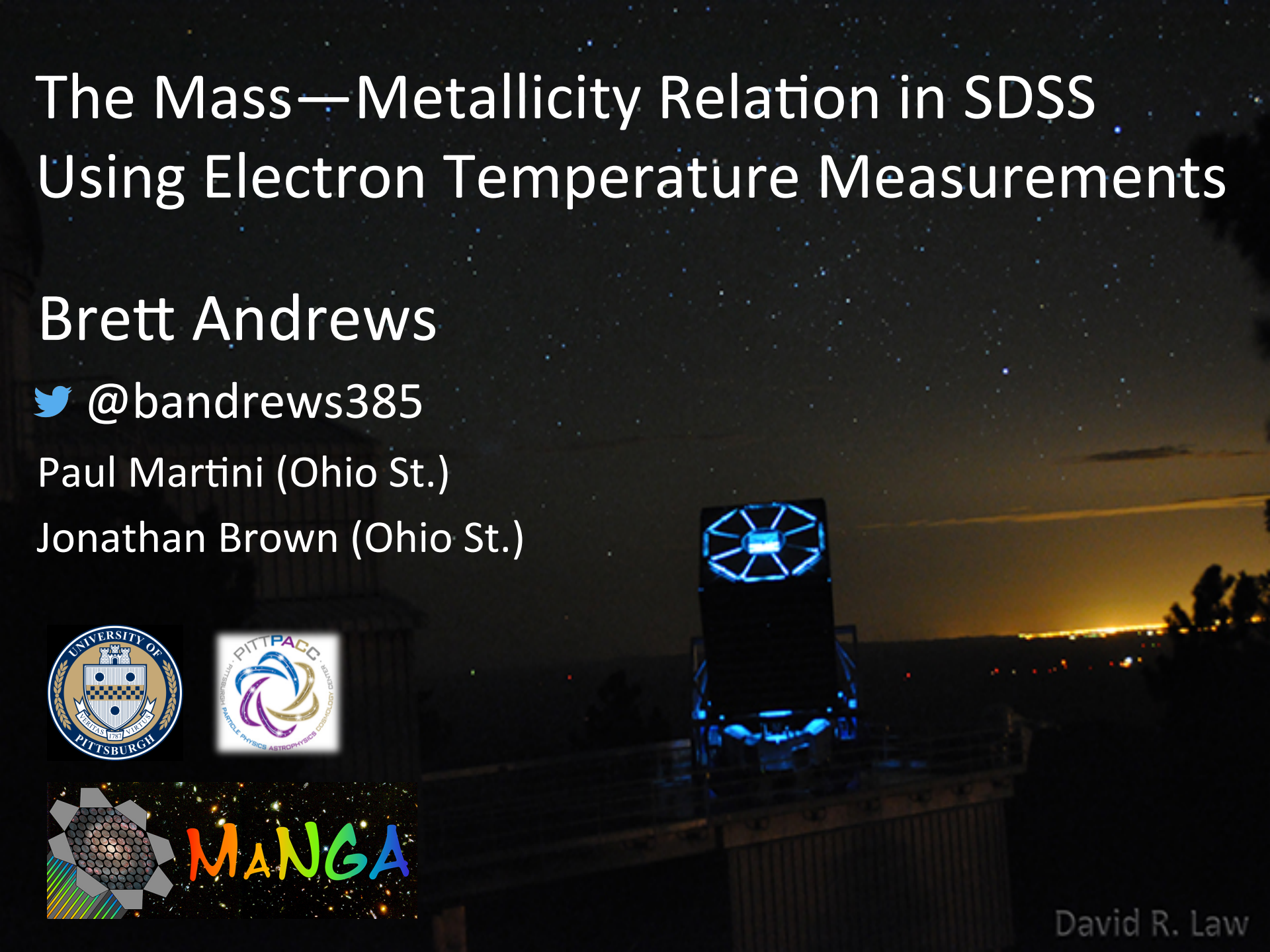
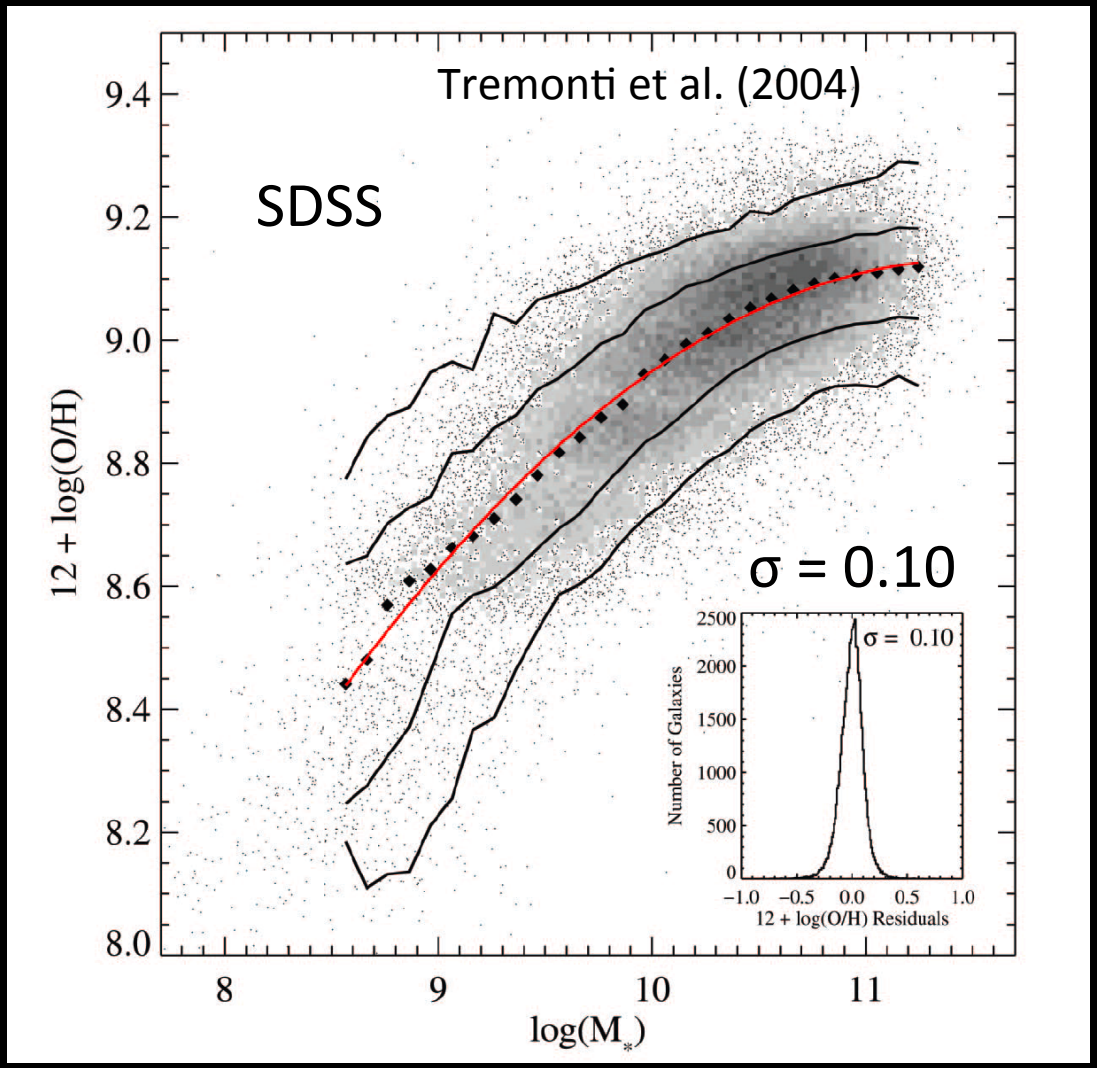


Mass—Metallicity Relation



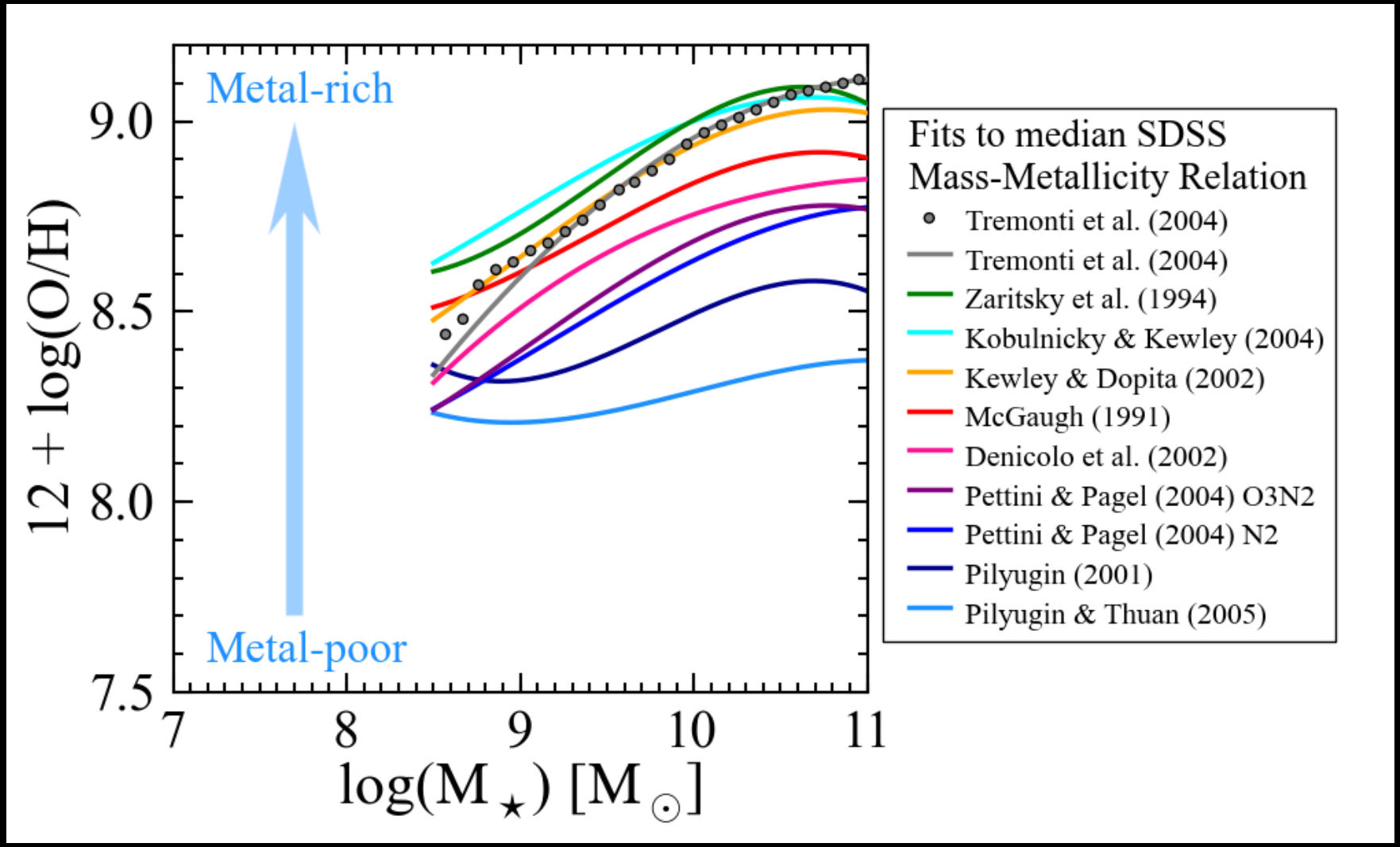
Chemical evolution is governed by

- Inflow
- Enrichment
- Outflow

Features:

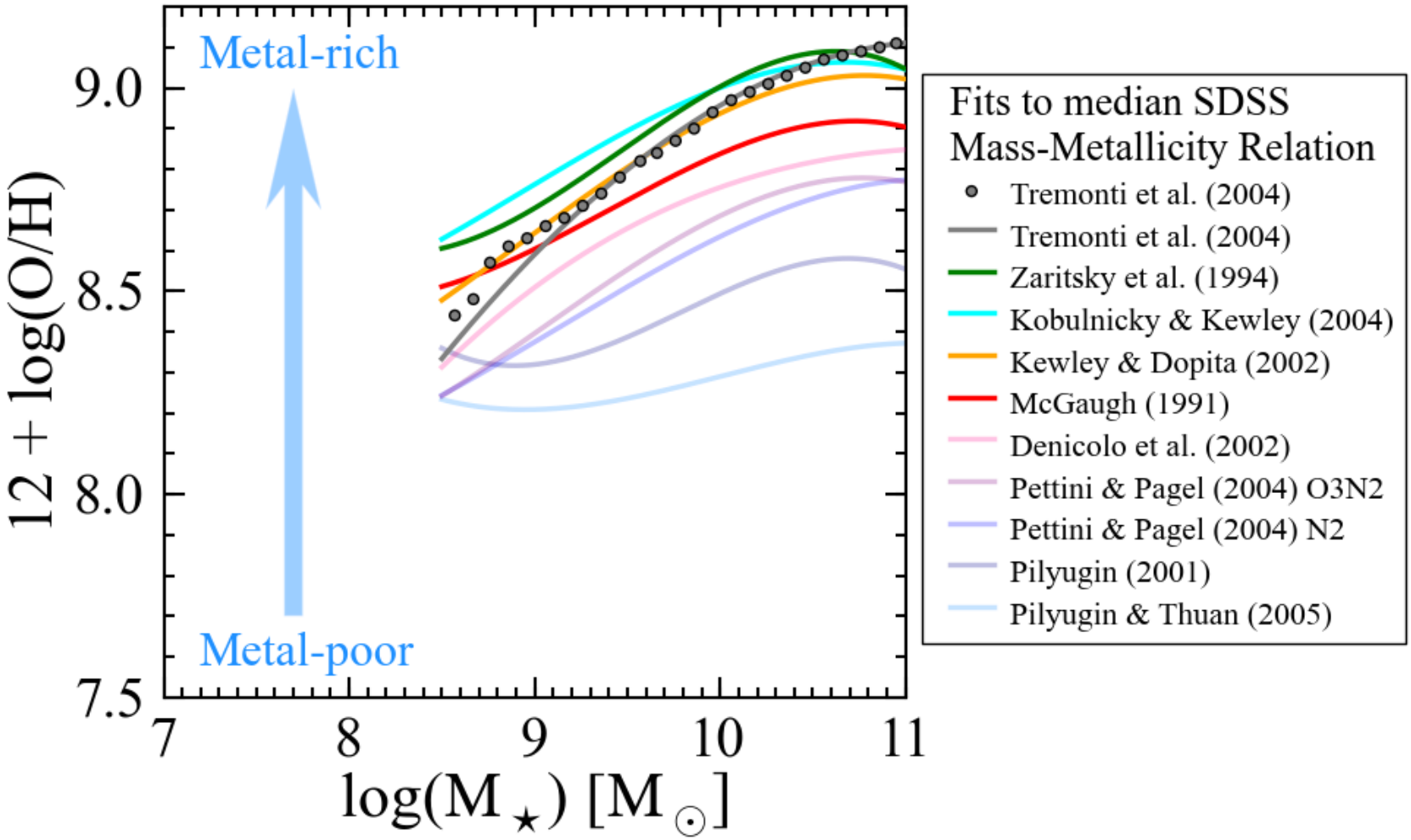
- normalization
- low mass slope
- turnover mass
- scatter
- evolution
- SFR-dependence

Strong line metallicities suffer from large systematic uncertainties.



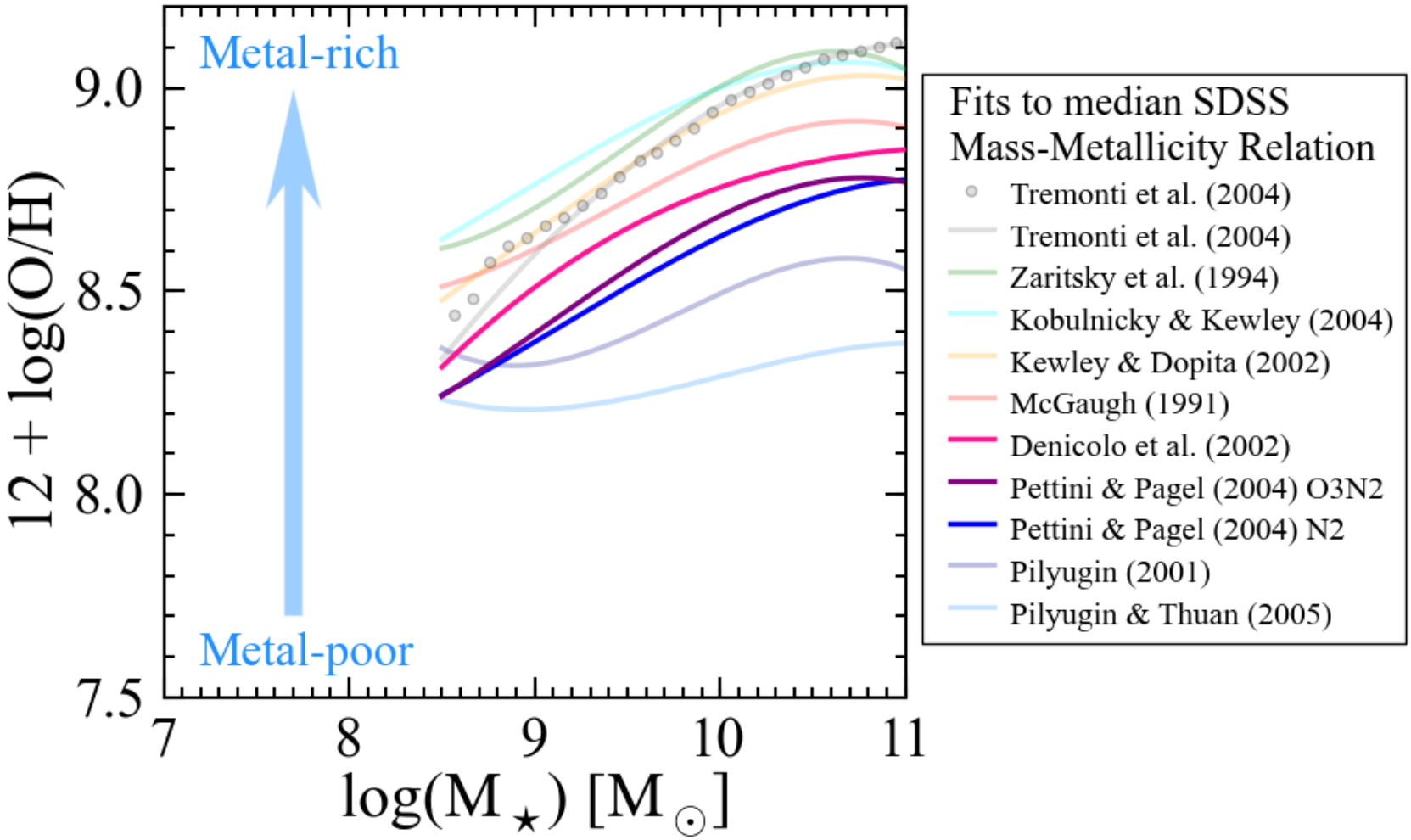
Fits from Kewley & Ellison (2008)

Theoretical Calibrations



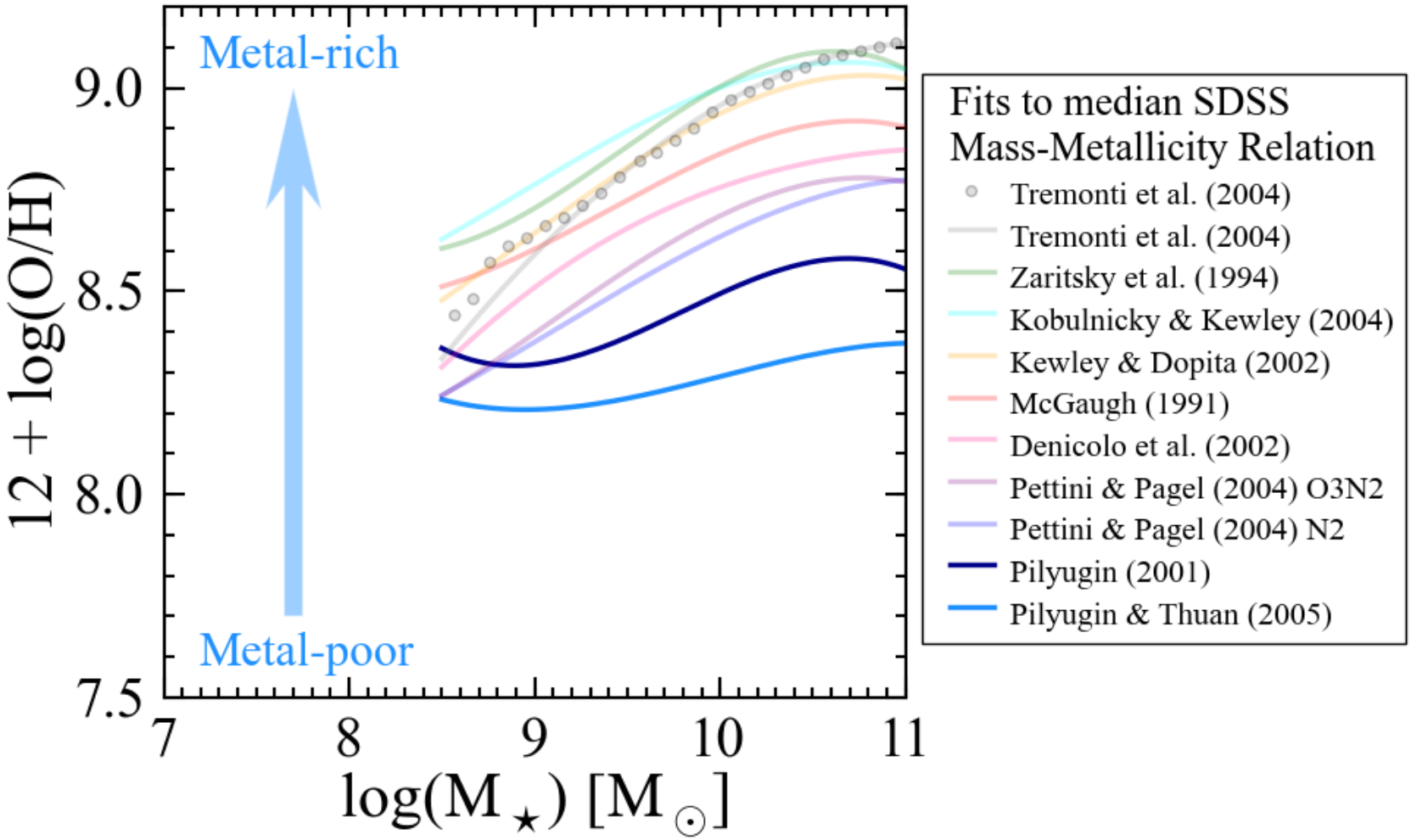
Fits from Kewley & Ellison (2008)

Semi-Empirical Calibrations



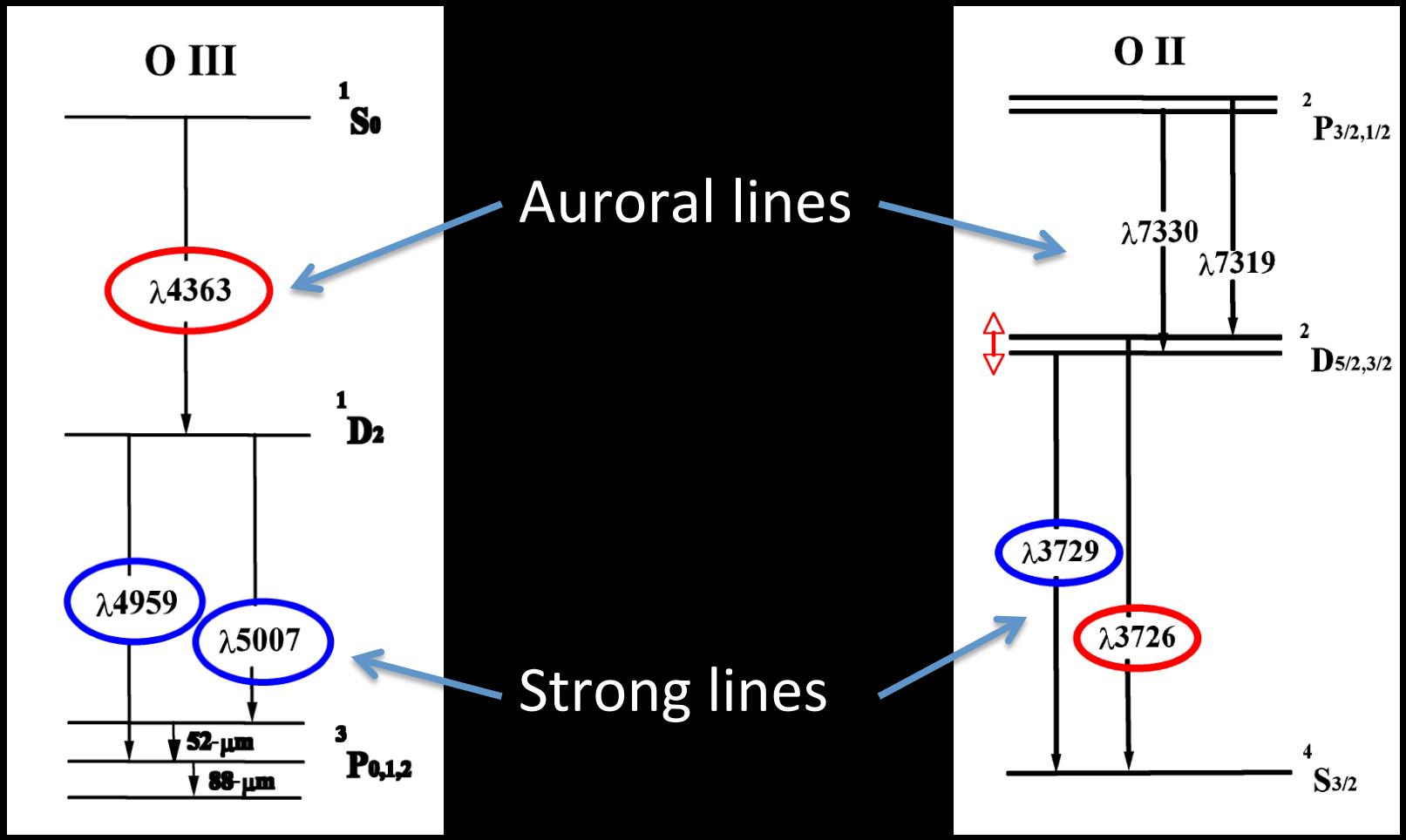
Fits from Kewley & Ellison (2008)

Empirical Calibrations



Fits from Kewley & Ellison (2008)

Auroral Lines: Temperature-sensitive



M. Westmoquette

Direct Method

limiting factor

$$\frac{[\mathrm{OIII}]\ \lambda 4363}{[\mathrm{OIII}]\ \lambda\lambda 4959, 5007}$$

$$\downarrow$$

$$\frac{[\mathrm{OIII}]\ \lambda\lambda 4959, 5007}{\mathrm{H}\beta} + \mathrm{Te[OIII]}$$

$$\downarrow$$

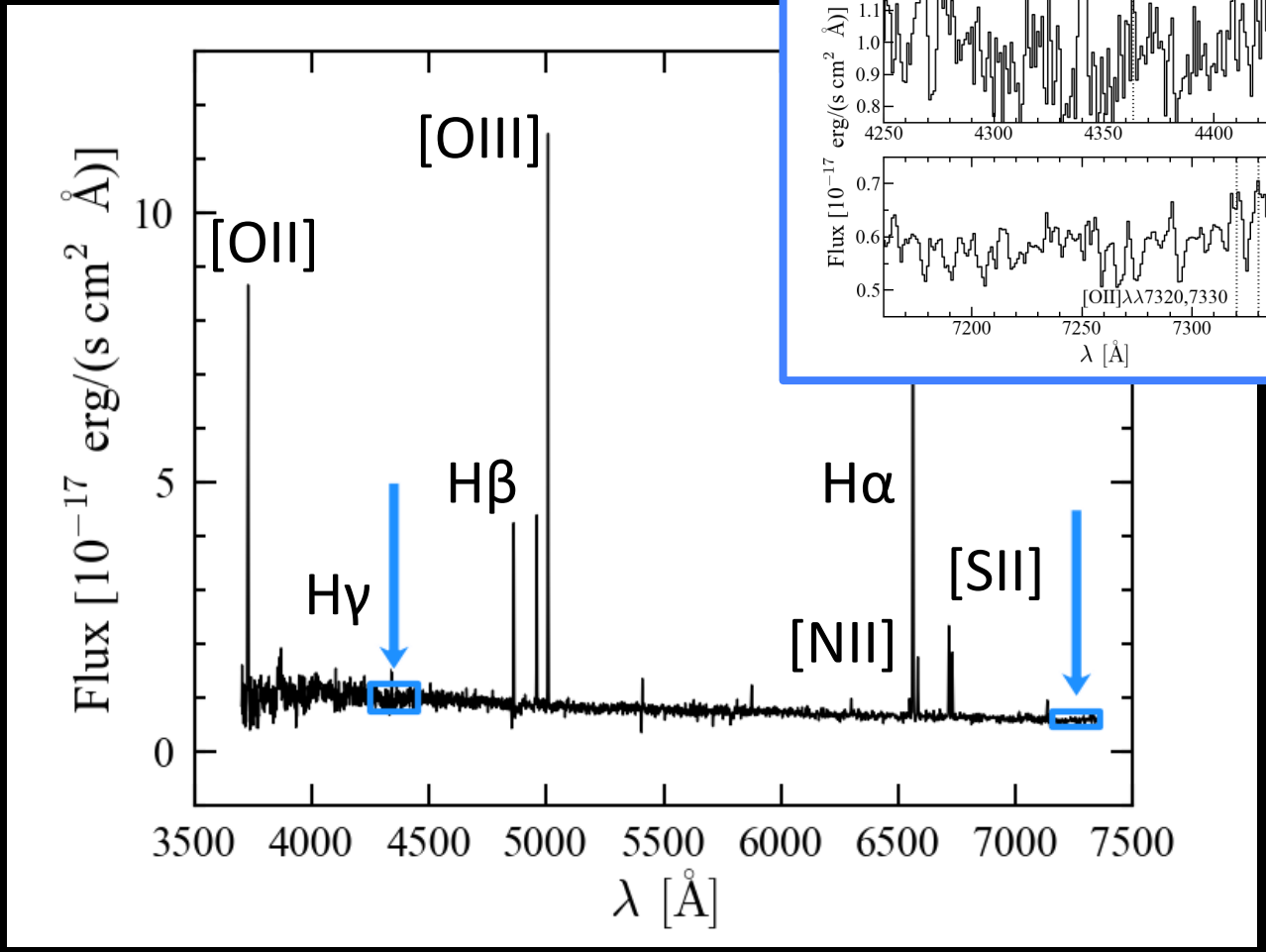
$$\frac{\mathrm{O{+}{+}}}{\mathrm{H}}$$

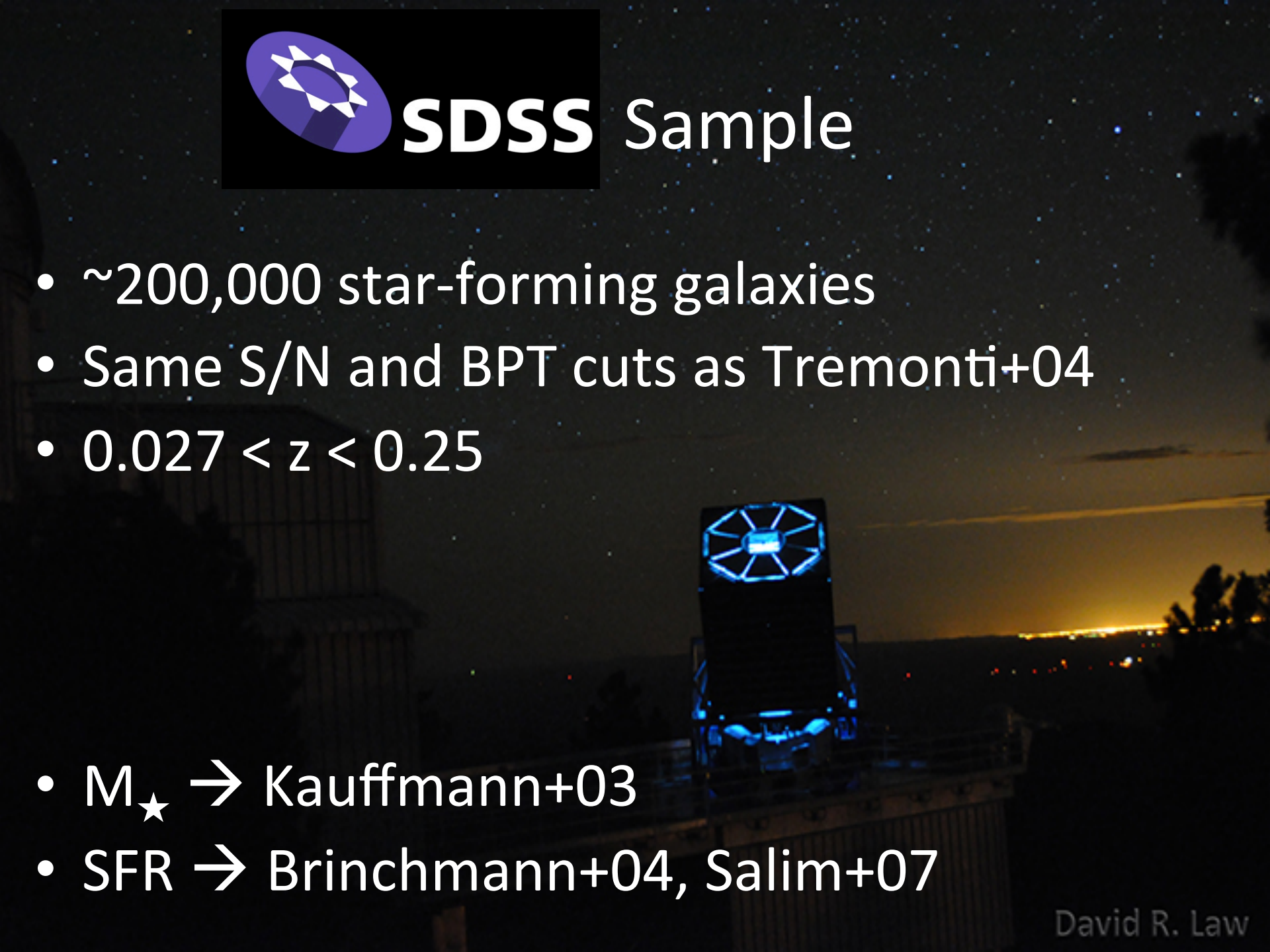
$$\downarrow$$

Metallicity: $$\frac{\mathrm{O}}{\mathrm{H}} = \frac{\mathrm{O{+}}}{\mathrm{H}} + \frac{\mathrm{O{+}{+}}}{\mathrm{H}}$$

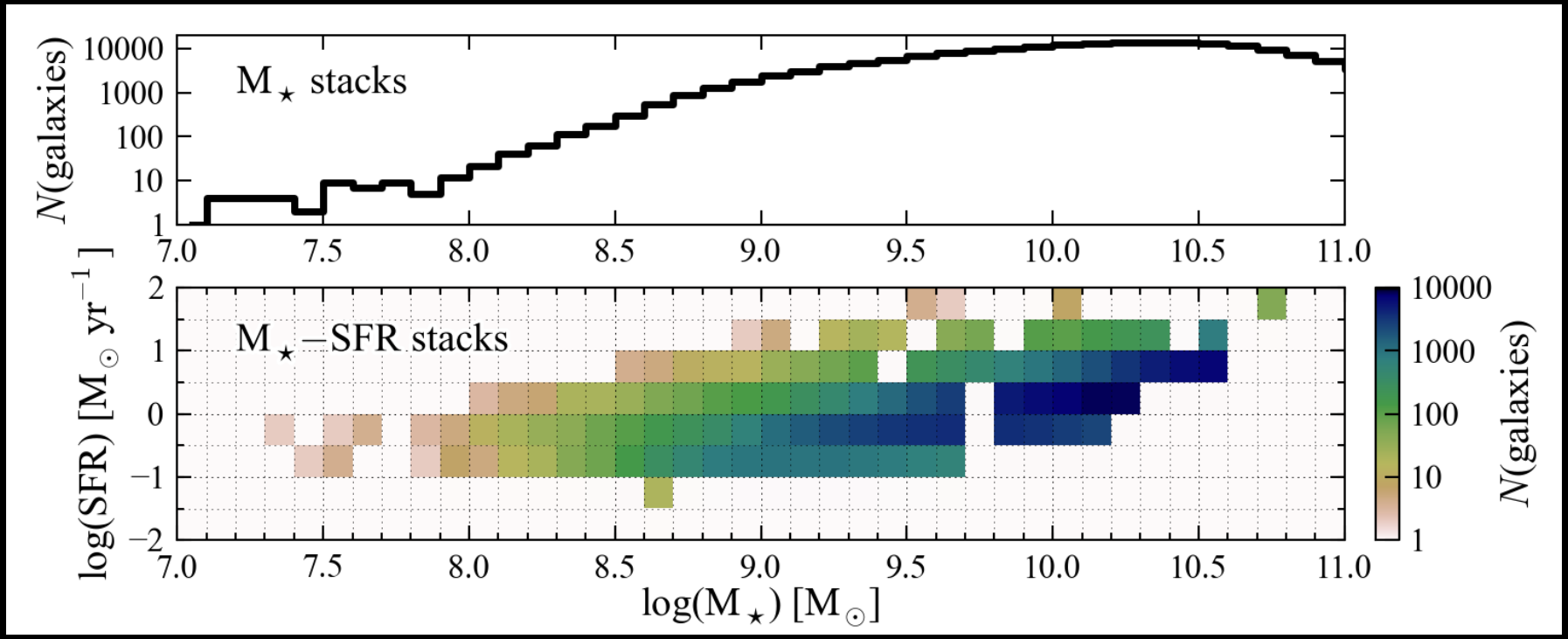
(Repeat for O+)

Auroral lines are very weak



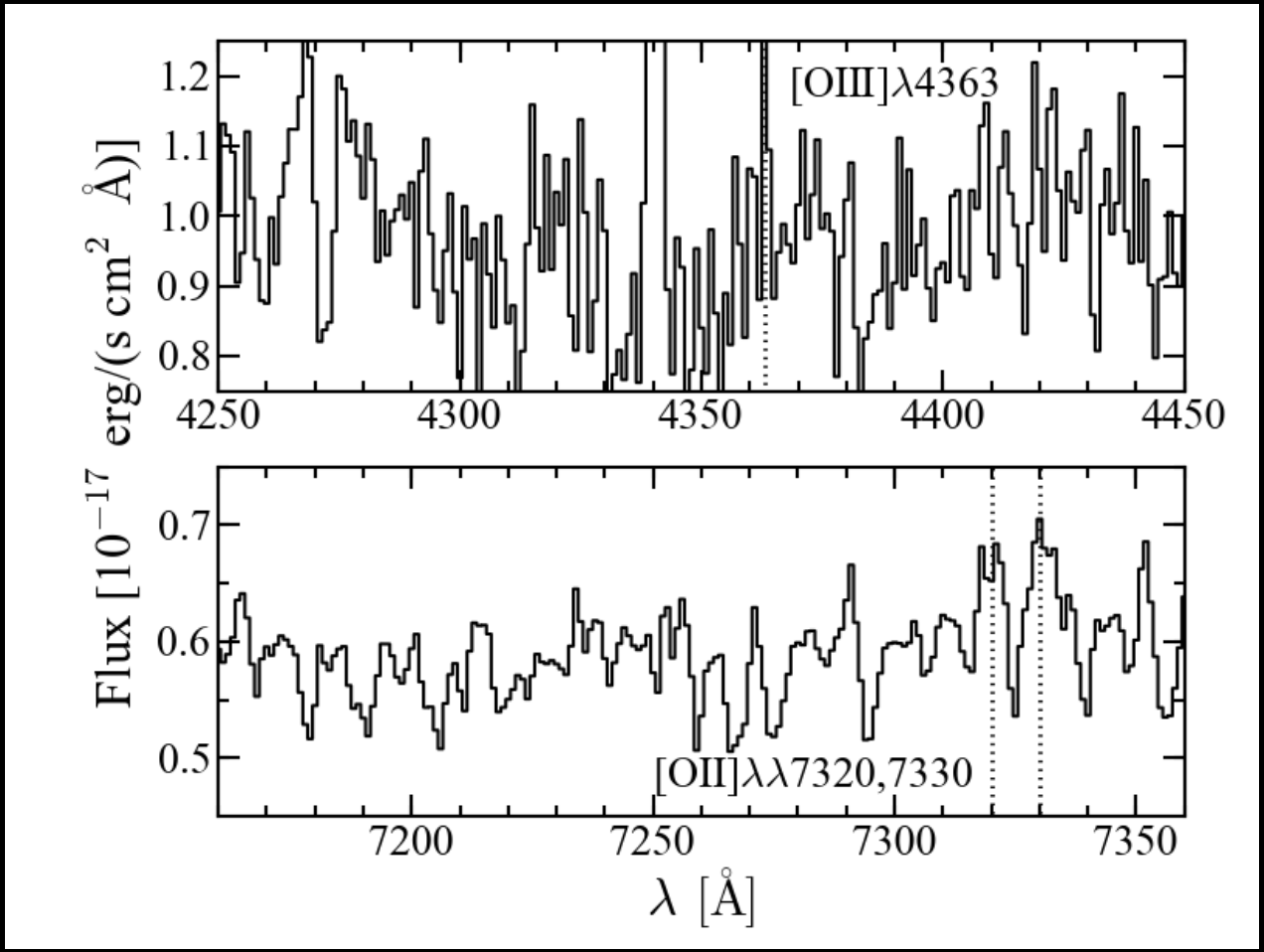

SDSS
Sample
• ~200,000 star-forming galaxies
• Same S/N and BPT cuts as Tremonti+04
• 0.027 < z < 0.25
• $M_\star$ → Kauffmann+03
• SFR → Brinchmann+04, Salim+07
David R. Law

Bin in Mstar and SFR

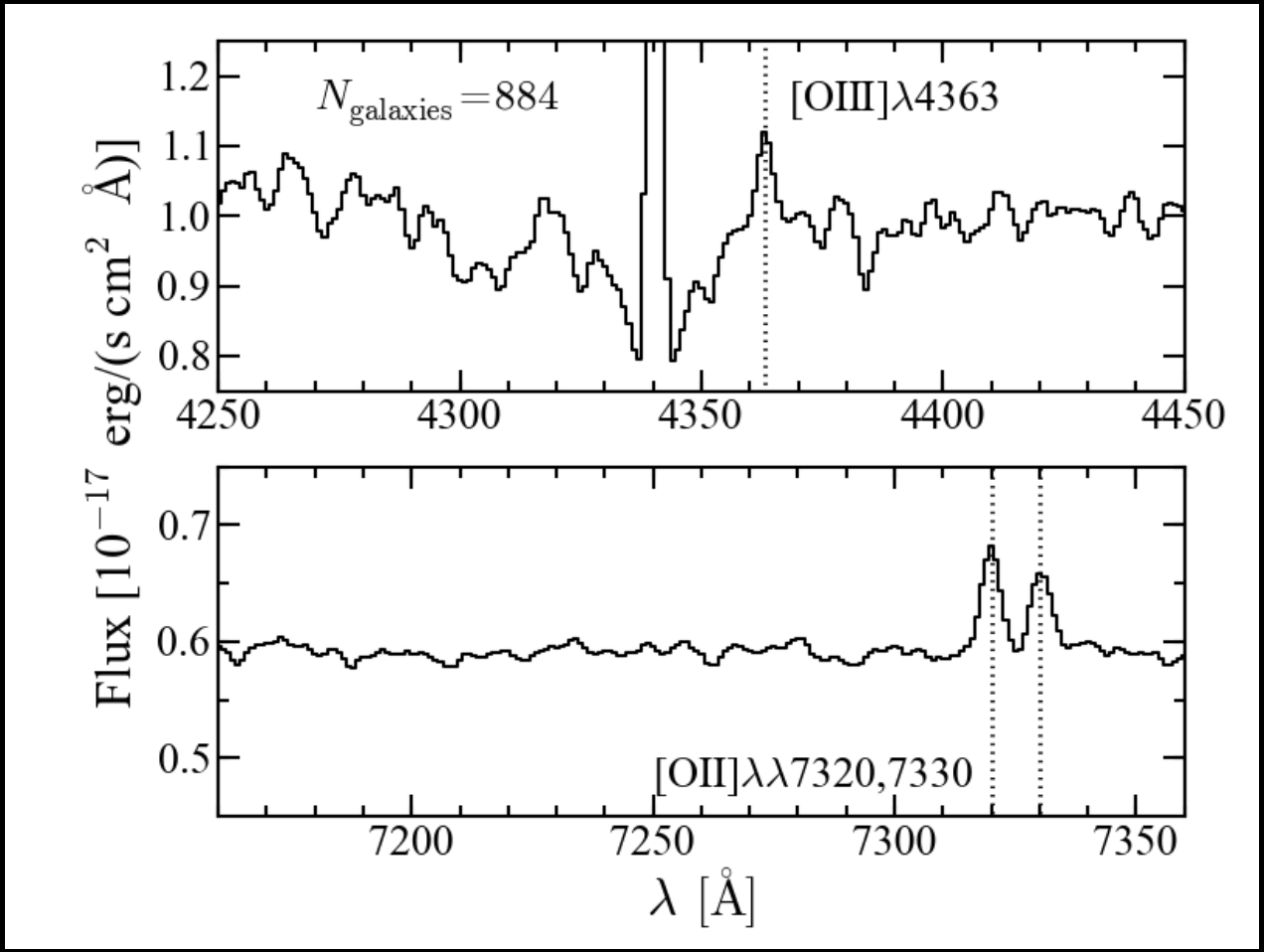


- We stacked in bins of
  - 0.1 dex in $M_\star$
  - 0.1 dex in $M_\star$ and 0.5 dex in SFR
- mass, SFR → metallicity

Auroral Lines of a Single Galaxy

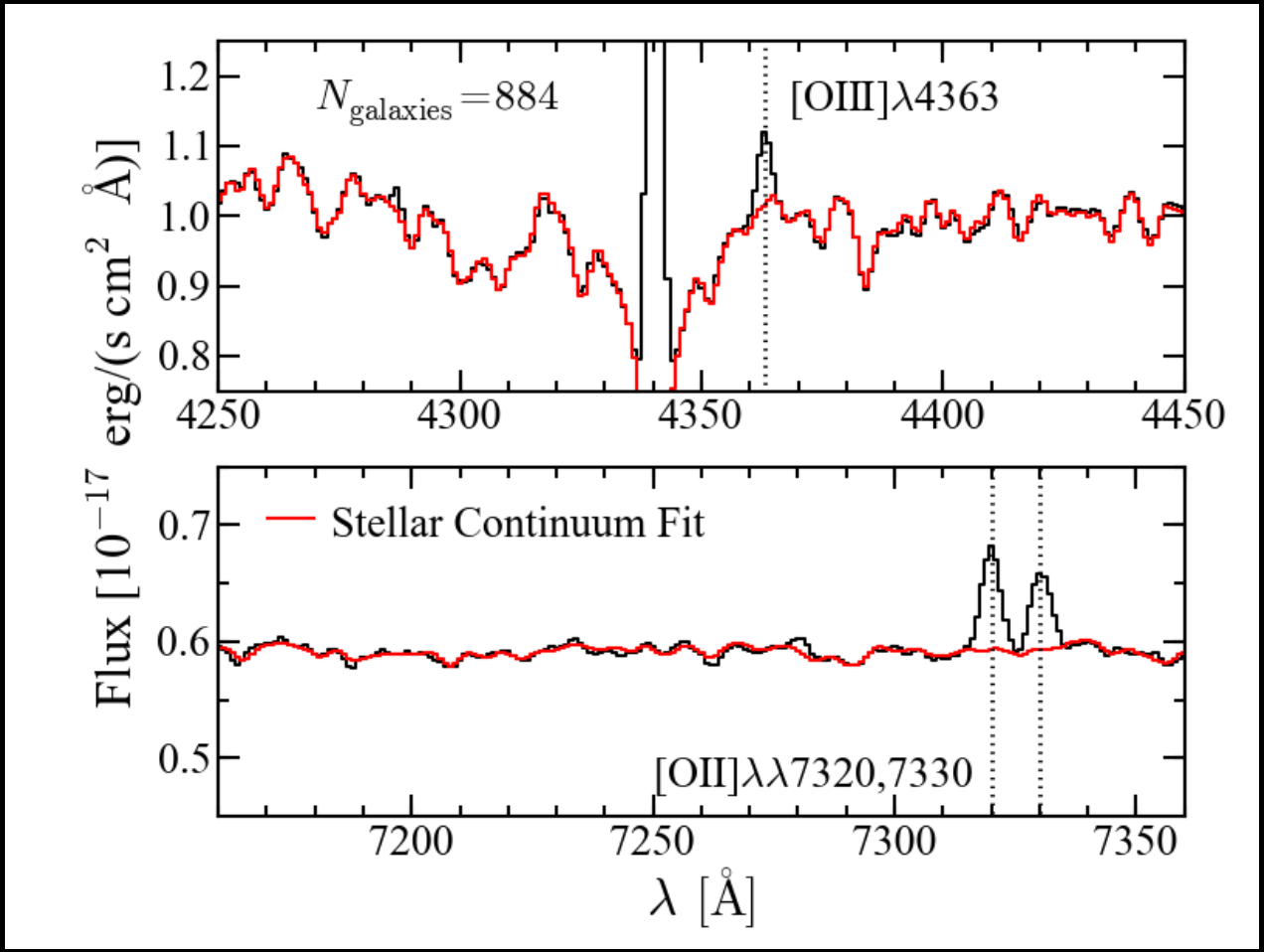


Stack of Galaxies



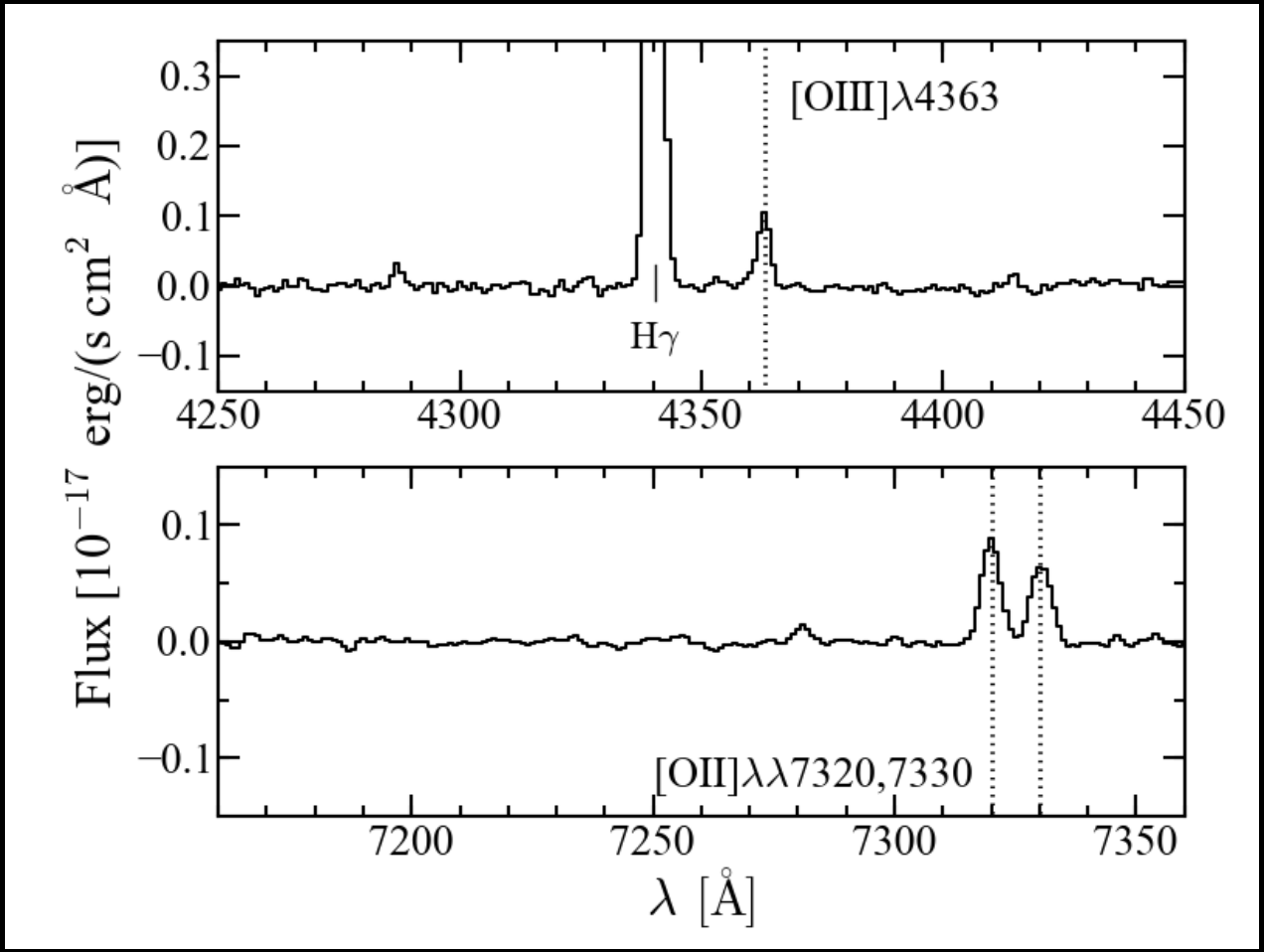
stellar absorption lines

Fit the Underlying Stellar Spectrum

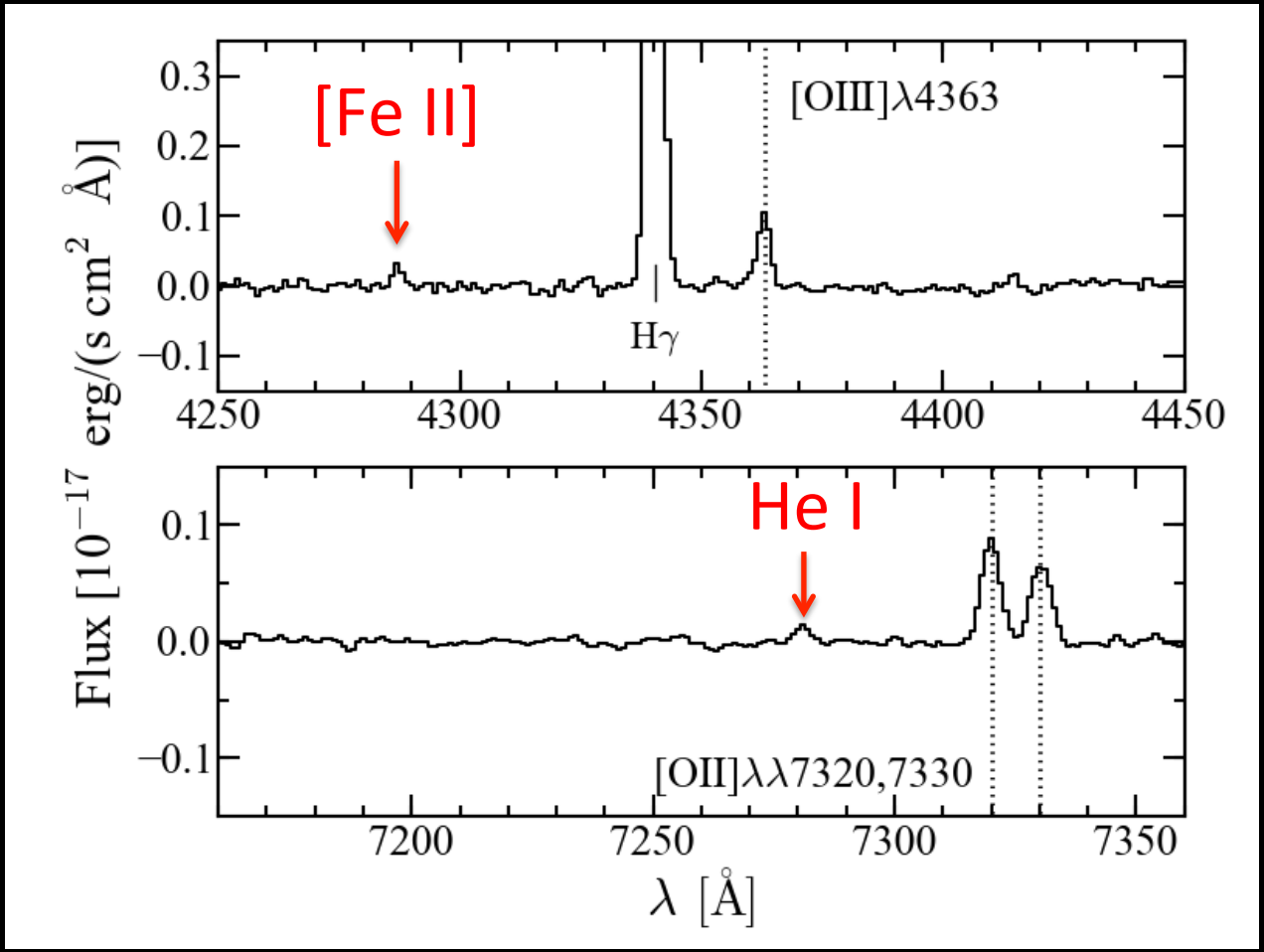


Stellar continuum fit with STARLIGHT stellar synthesis code (Cid Fernandes et al. 2005)

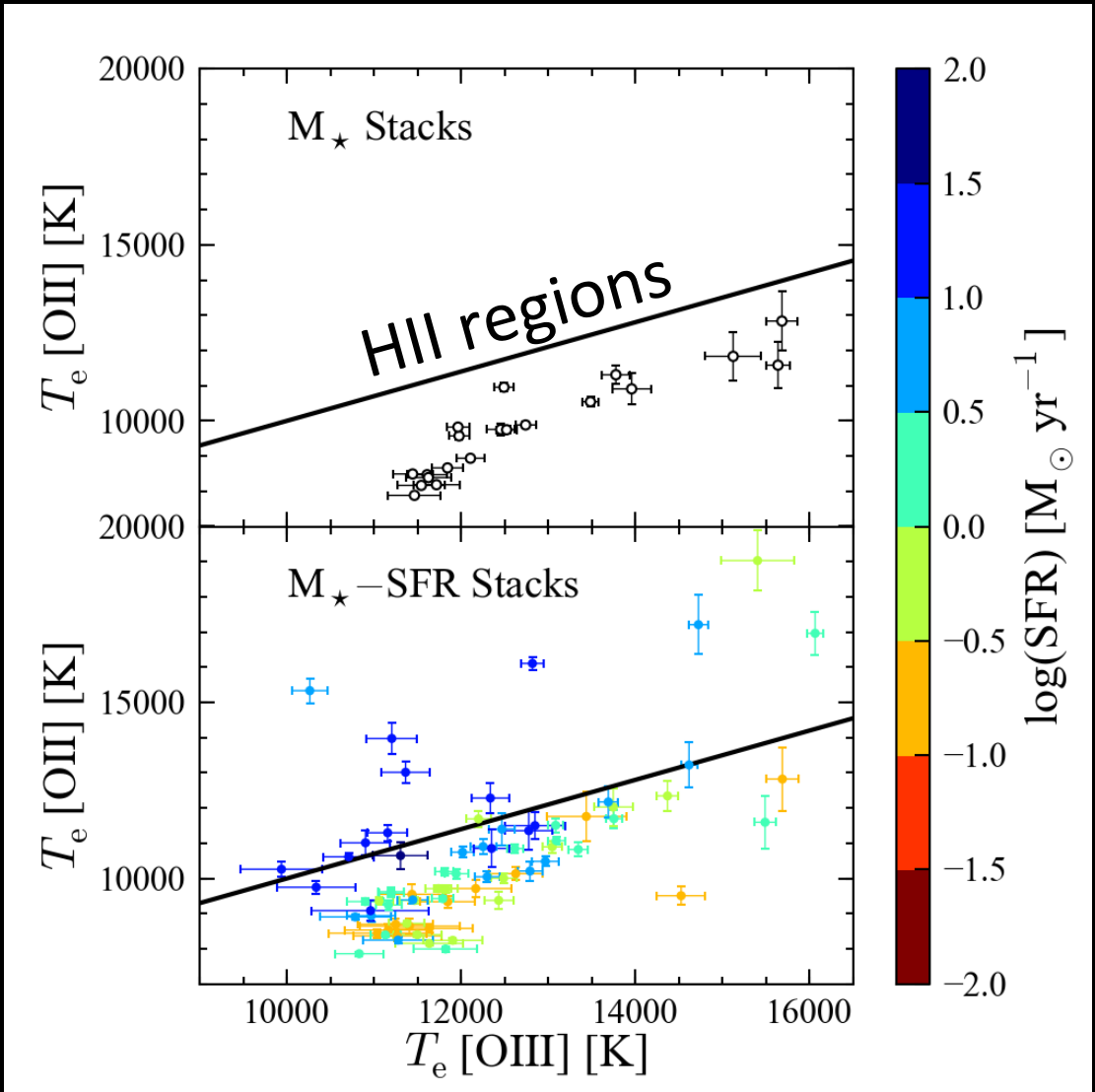
Final Spectrum



Final Spectrum

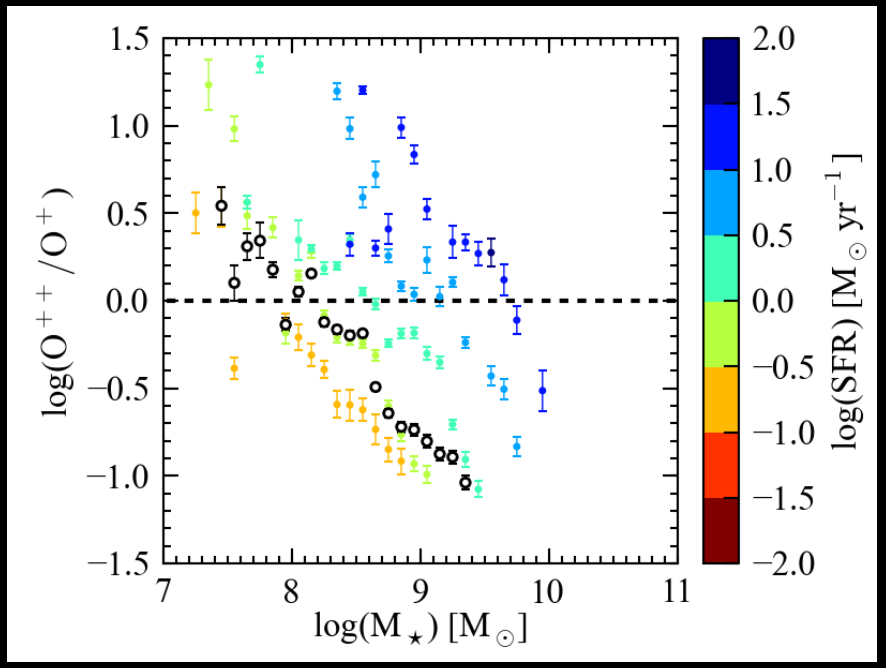


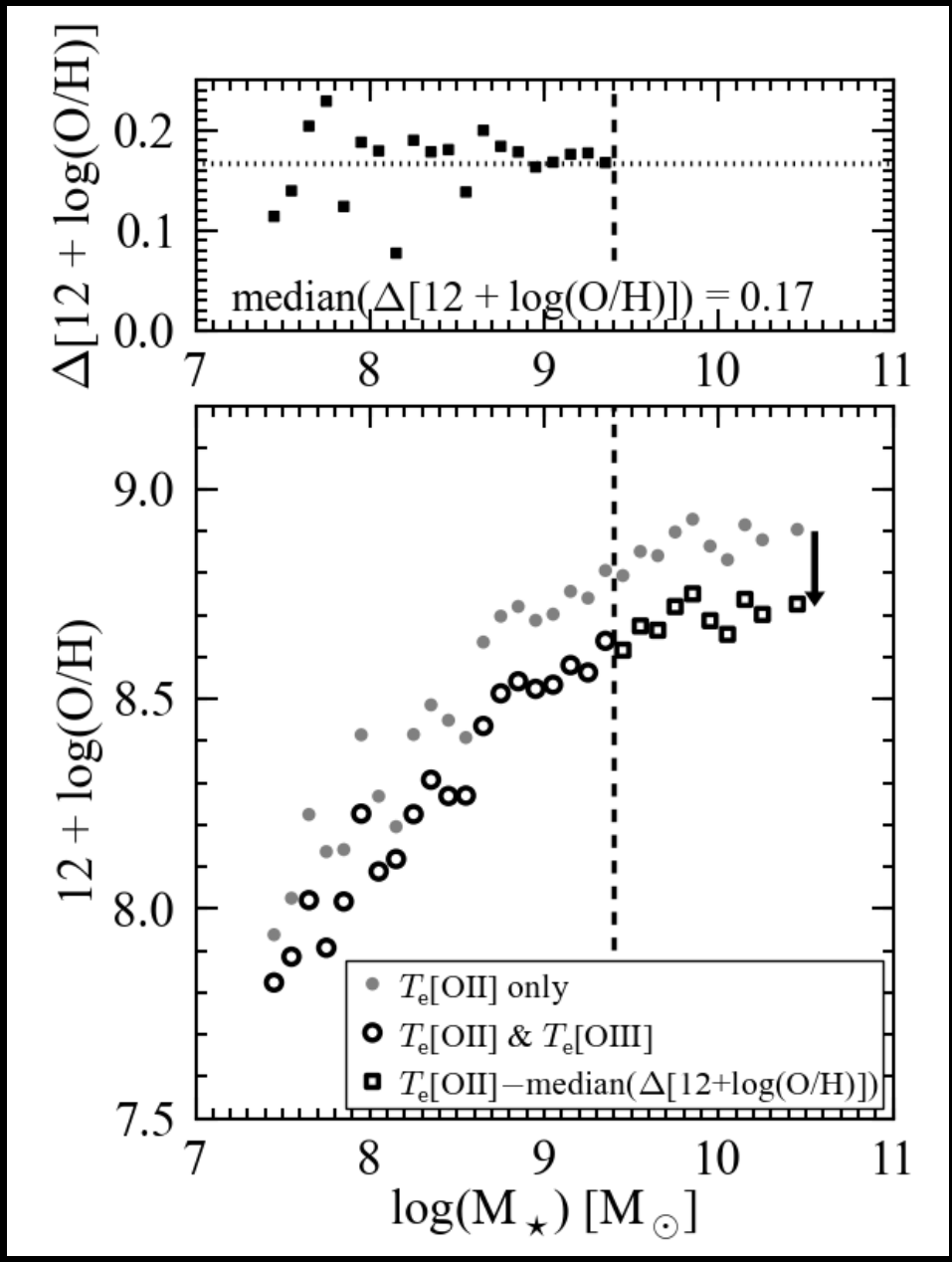
Electron Temperatures



Andrews & Martini (2013)

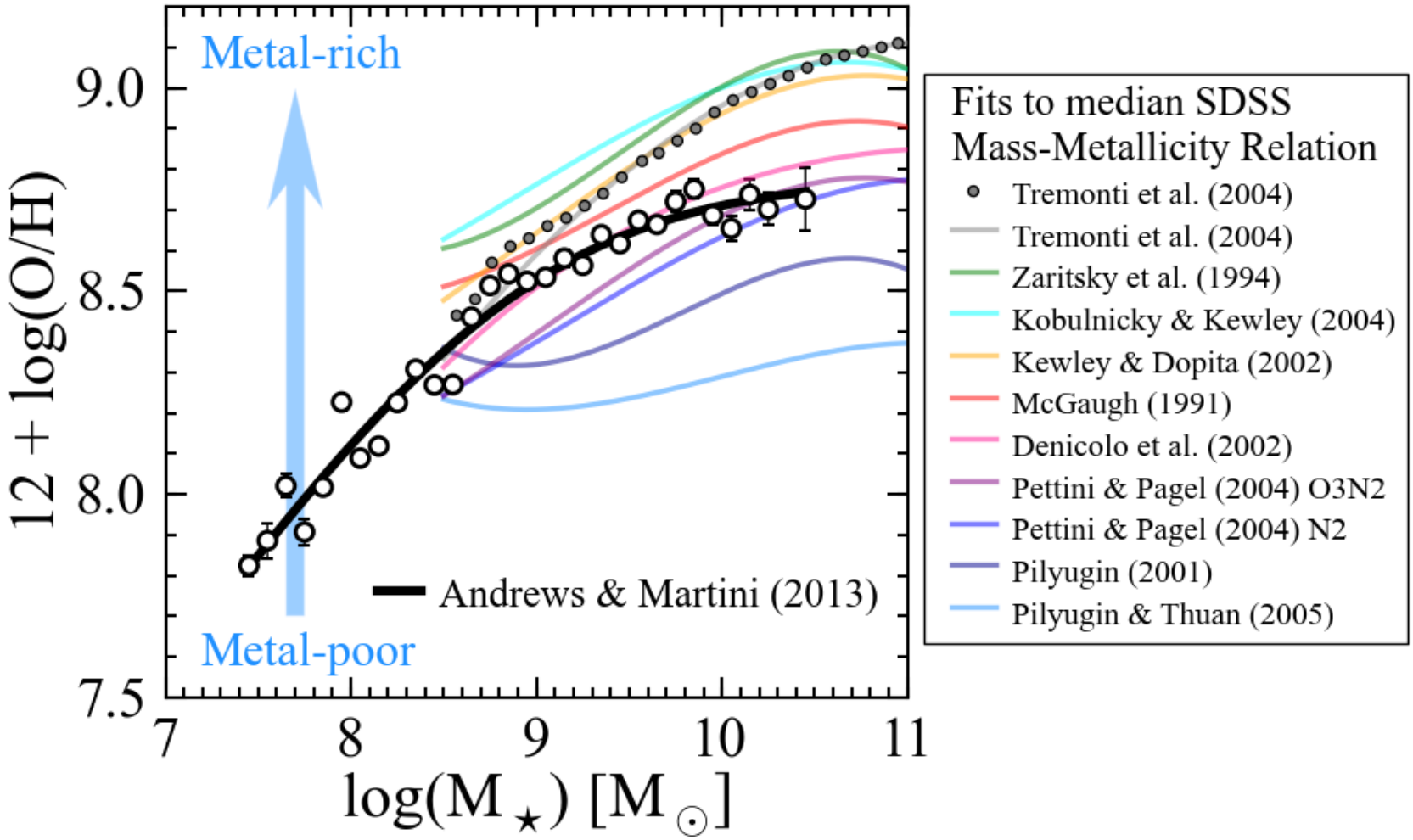
Accounting for undetected [OIII] λ4363





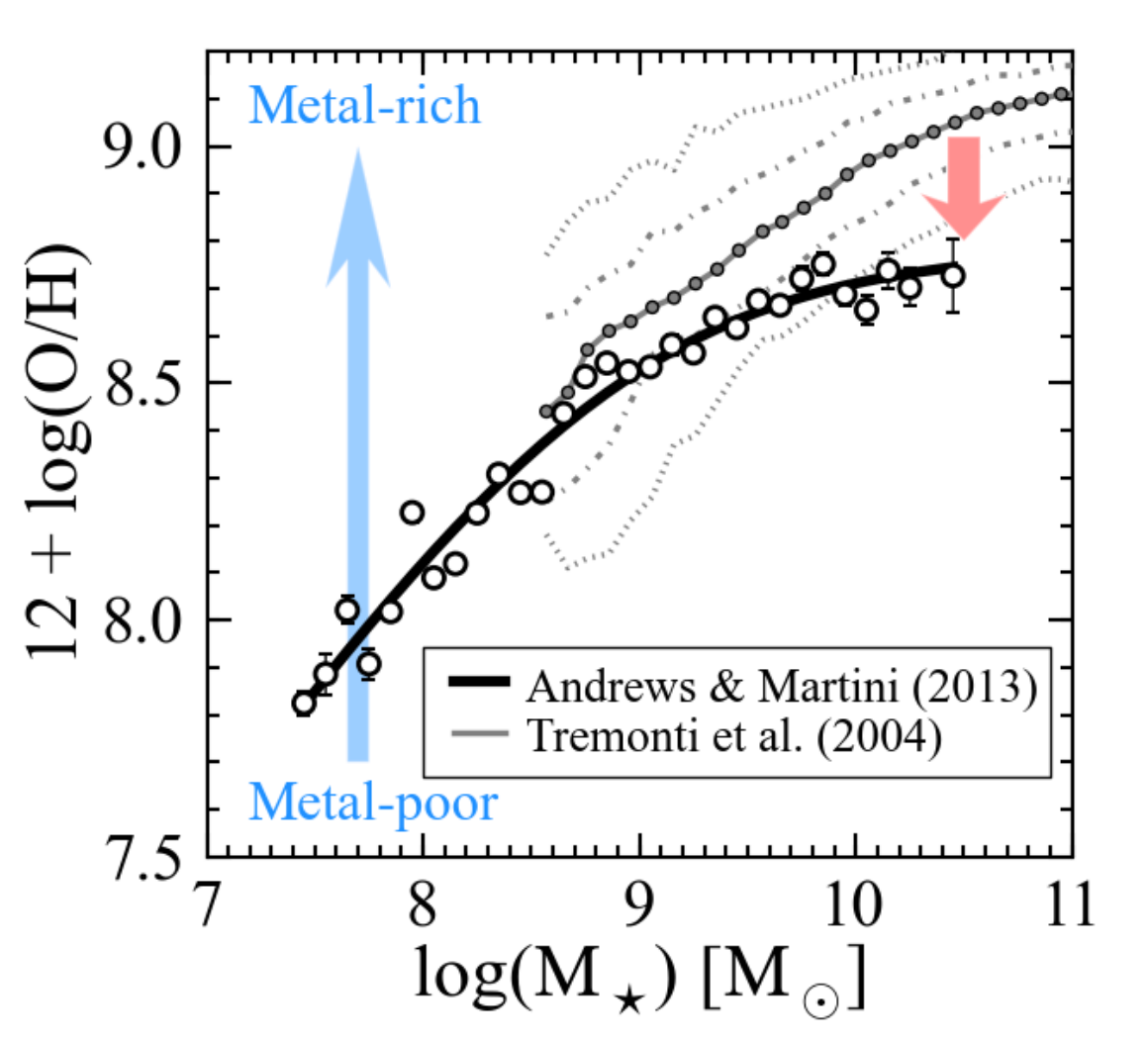
Andrews & Martini (2013)

Direct Method Mass—Metallicity Relation



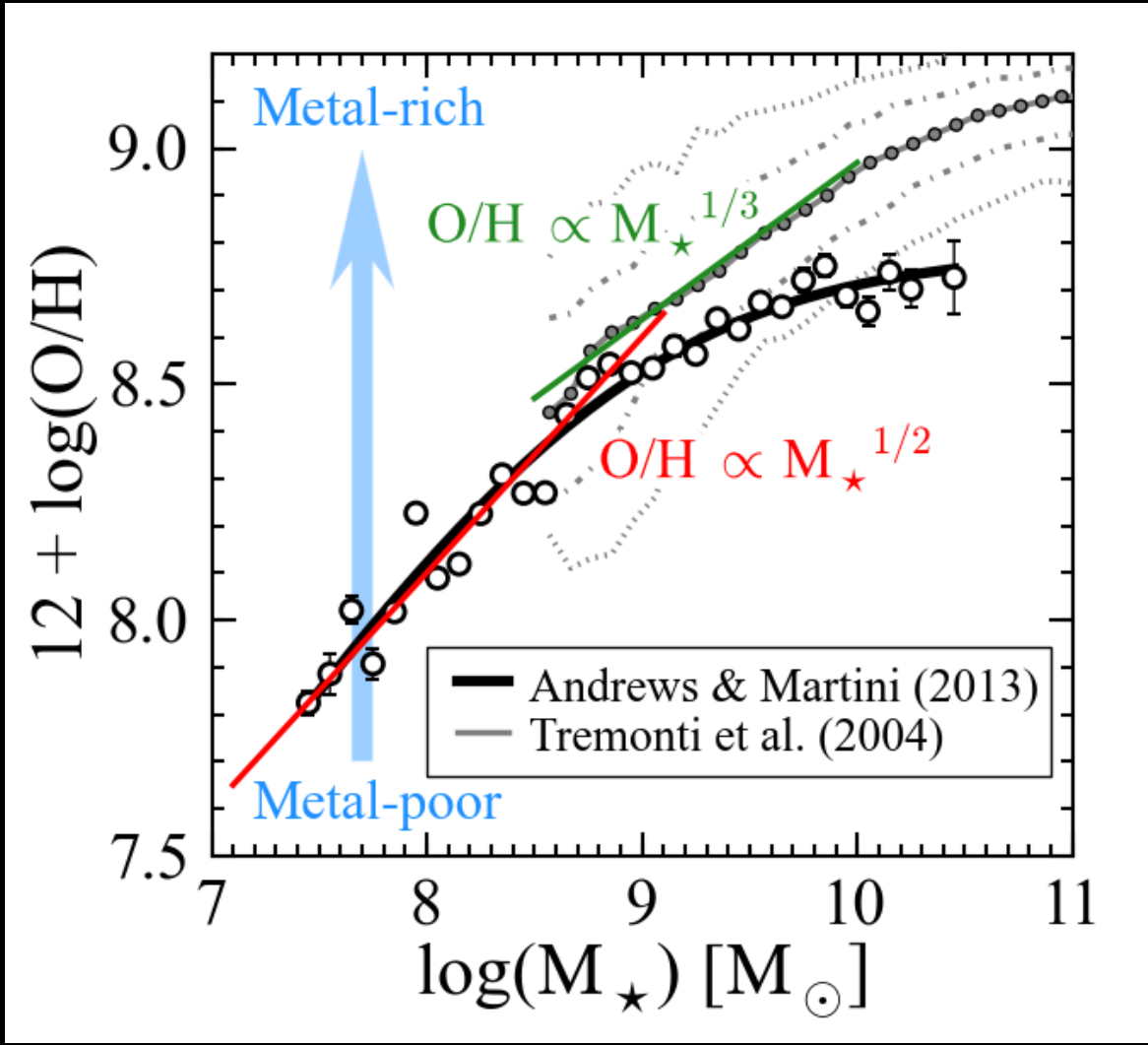
Fits from Kewley & Ellison (2008)

Normalization



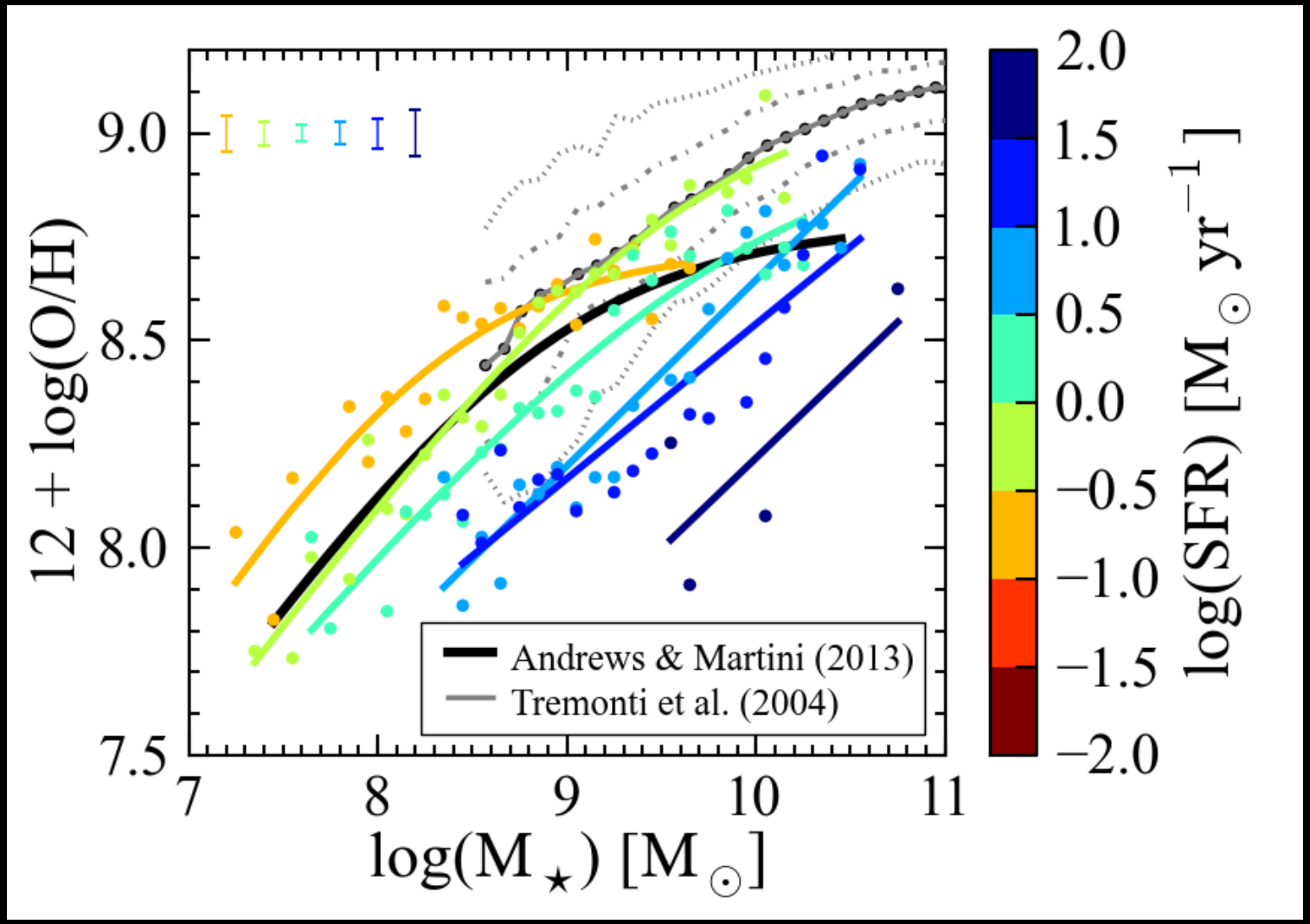
Galactic winds are efficient at ejecting metals…

Low Mass Slope

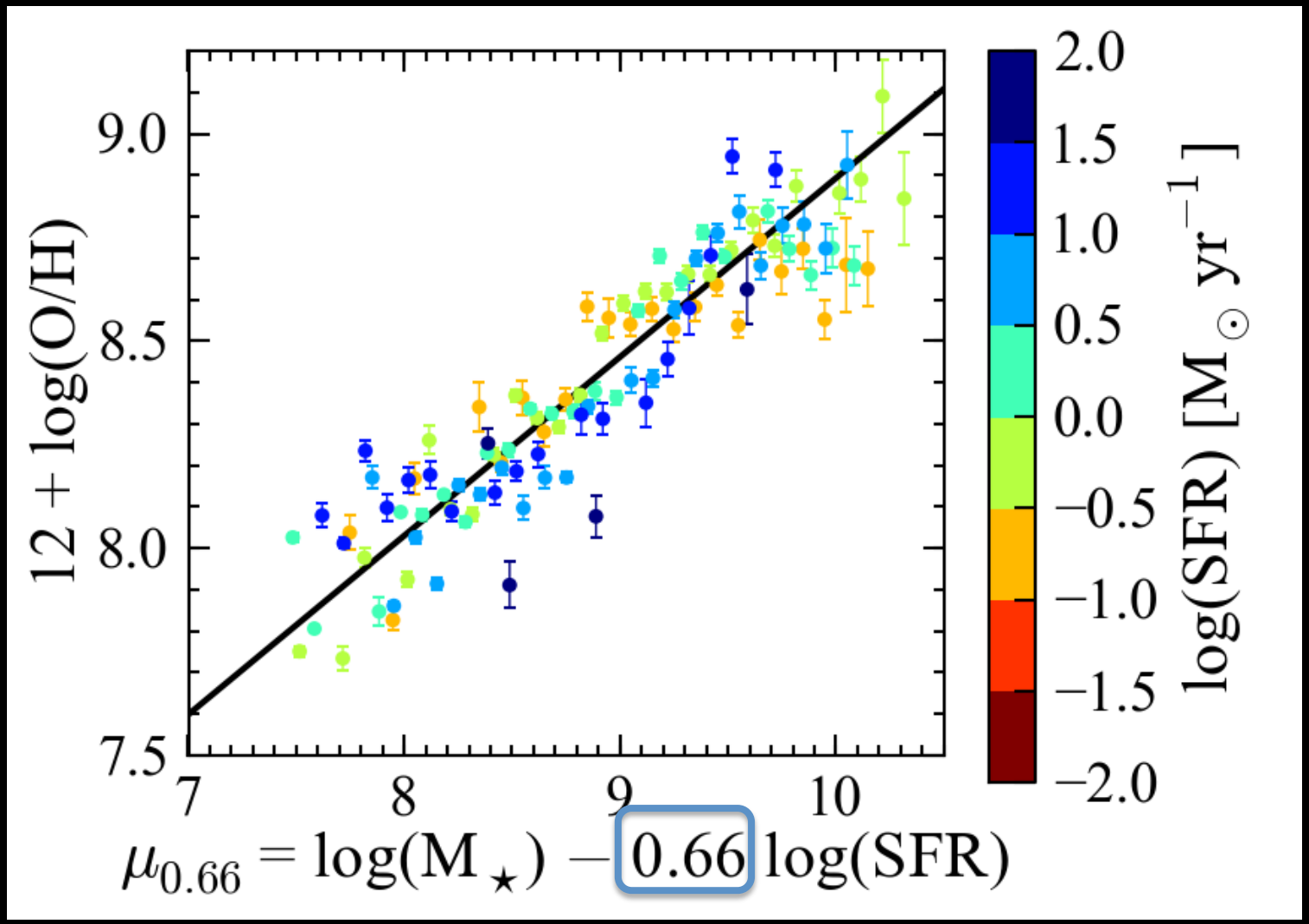


…especially in low mass galaxies.

SFR-dependence of the Mass-Metallicity Relation



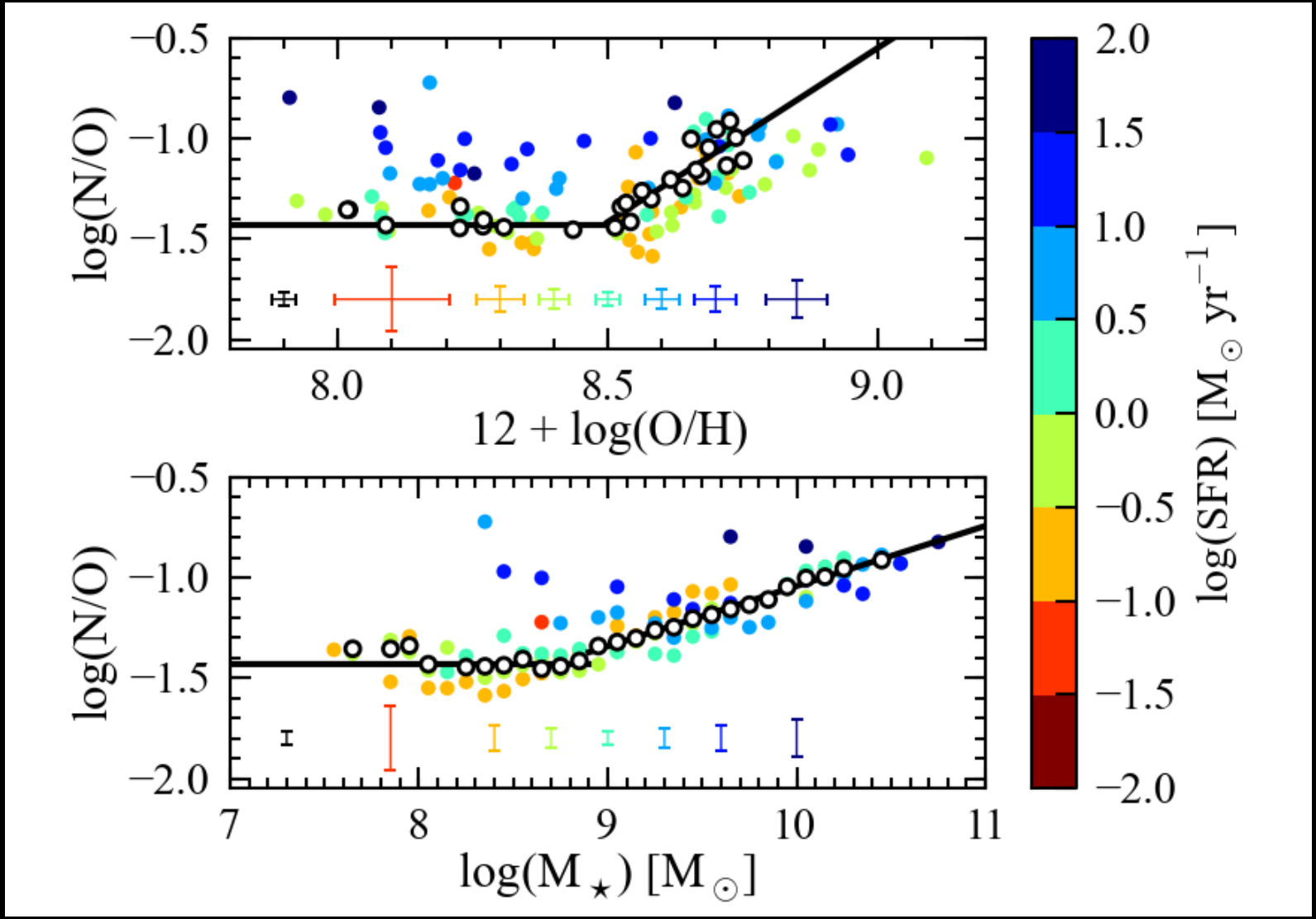
Direct Method M-Z-SFR Relation



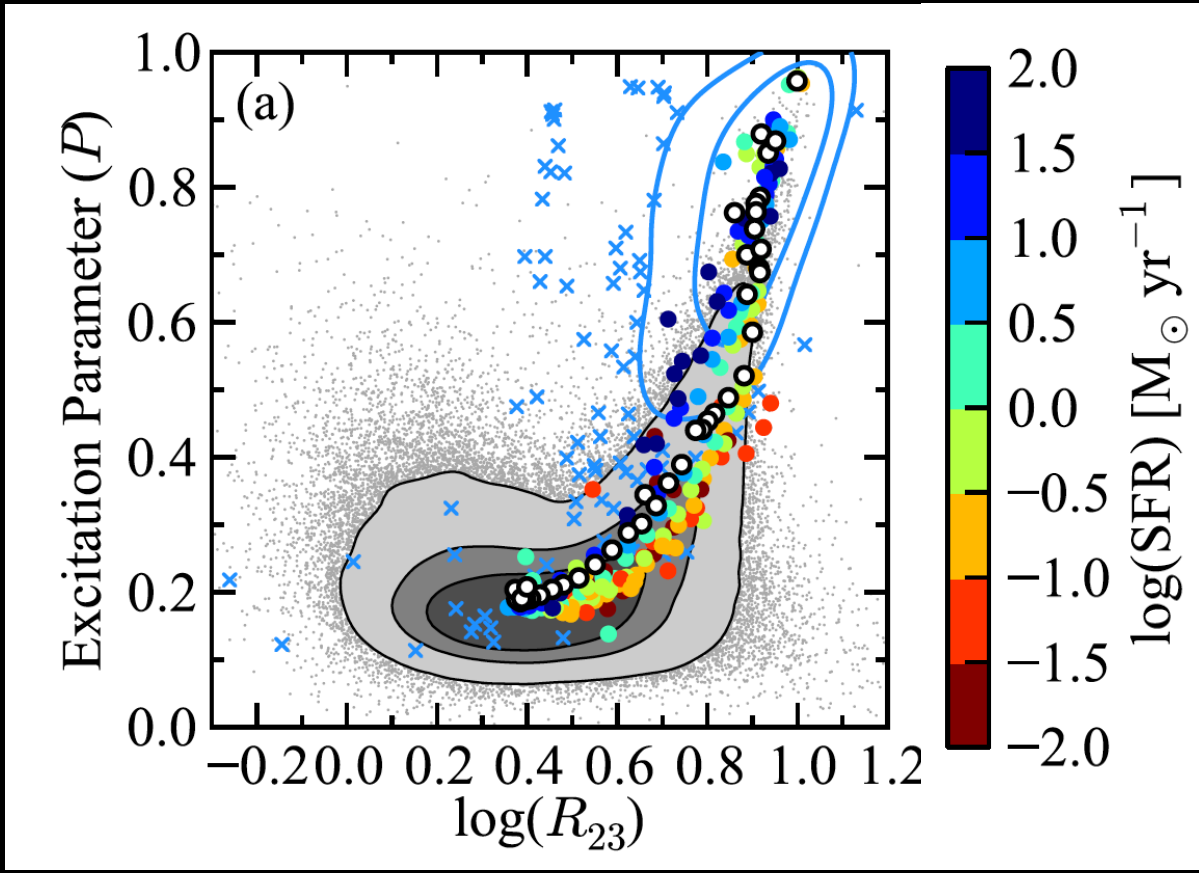
Mannucci+10: α = 0.32

Andrews & Martini (2013)

N/O



Andrews & Martini (2013)



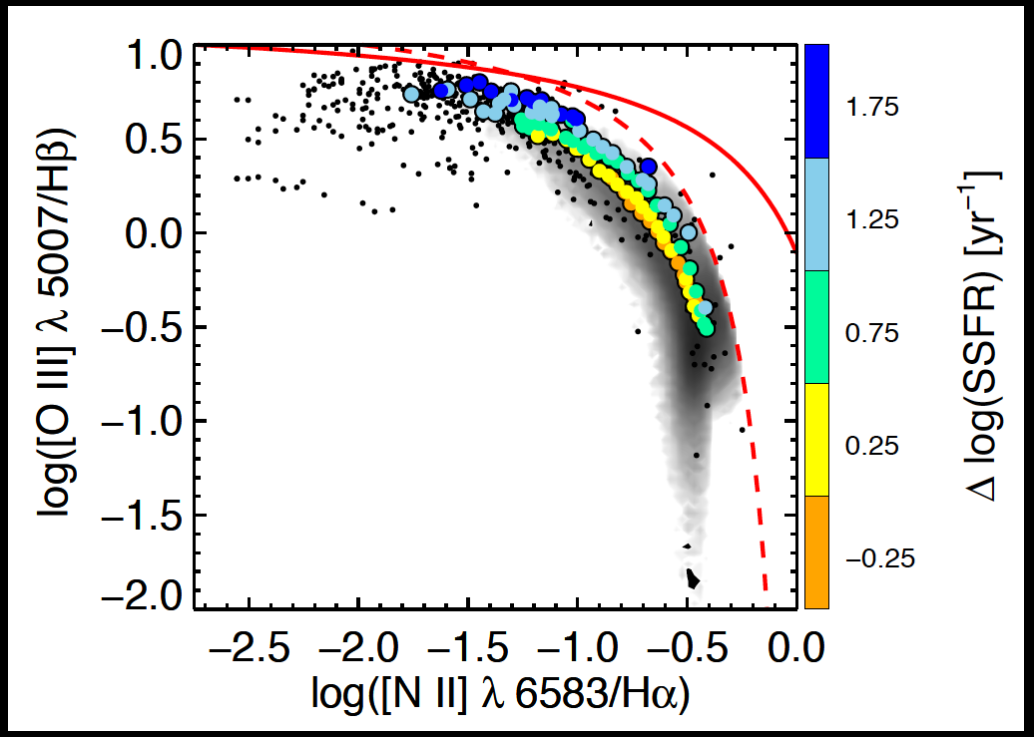
- Empirical calibrations are based on high excitation, low metallicity HII regions
- The stacks probe low excitation parameters and high metallicites, like the overall galaxy population.

Andrews & Martini (2013)

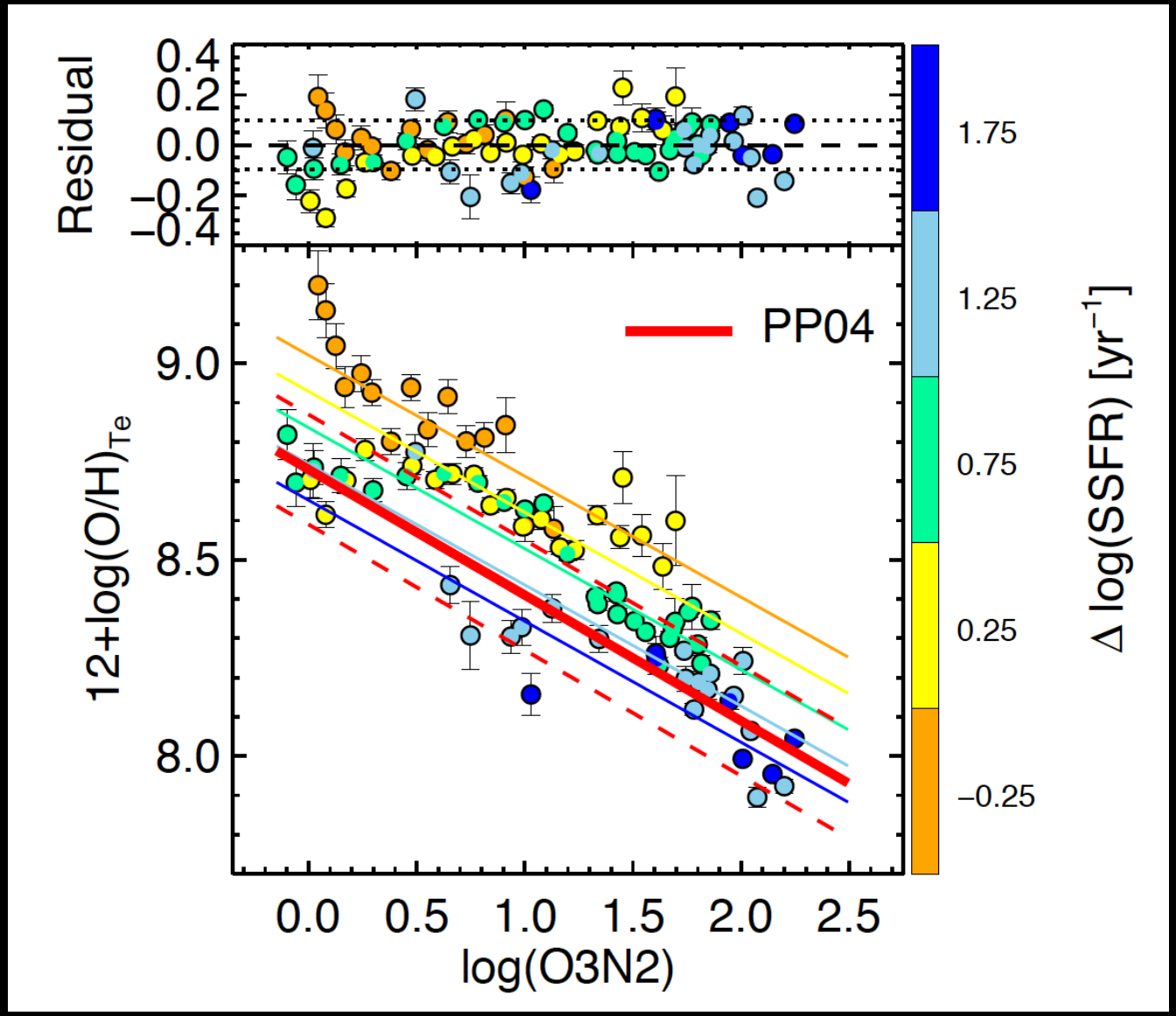
Recalibrating of Strong Line Diagnostics with Direct Method Stacks

Jonathan Brown

Brown, Martini, & Andrews (2015, in prep.)



- improved stacking scheme: bin relative to star-forming main sequence: Mstar & Δ log(SSFR)



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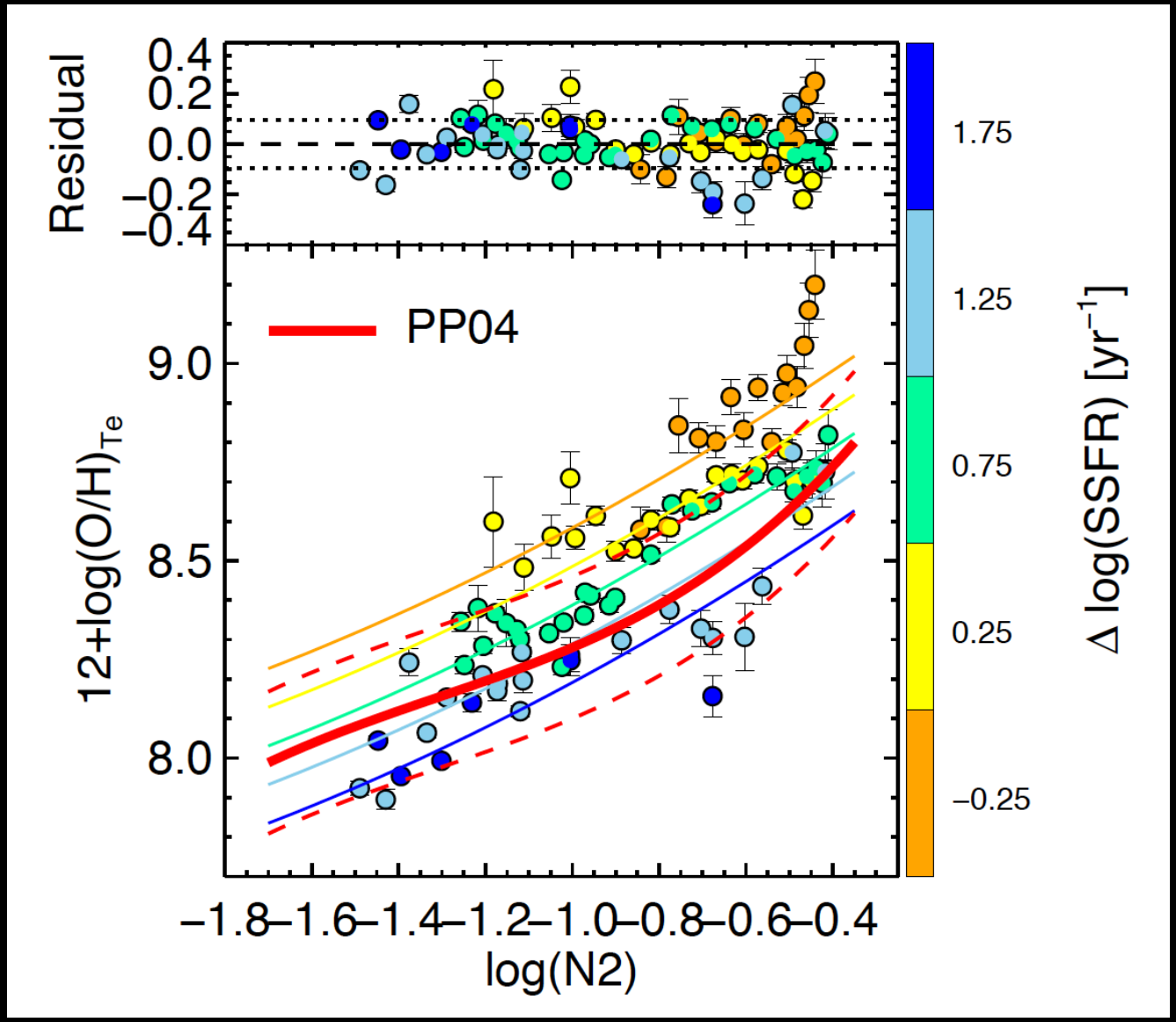

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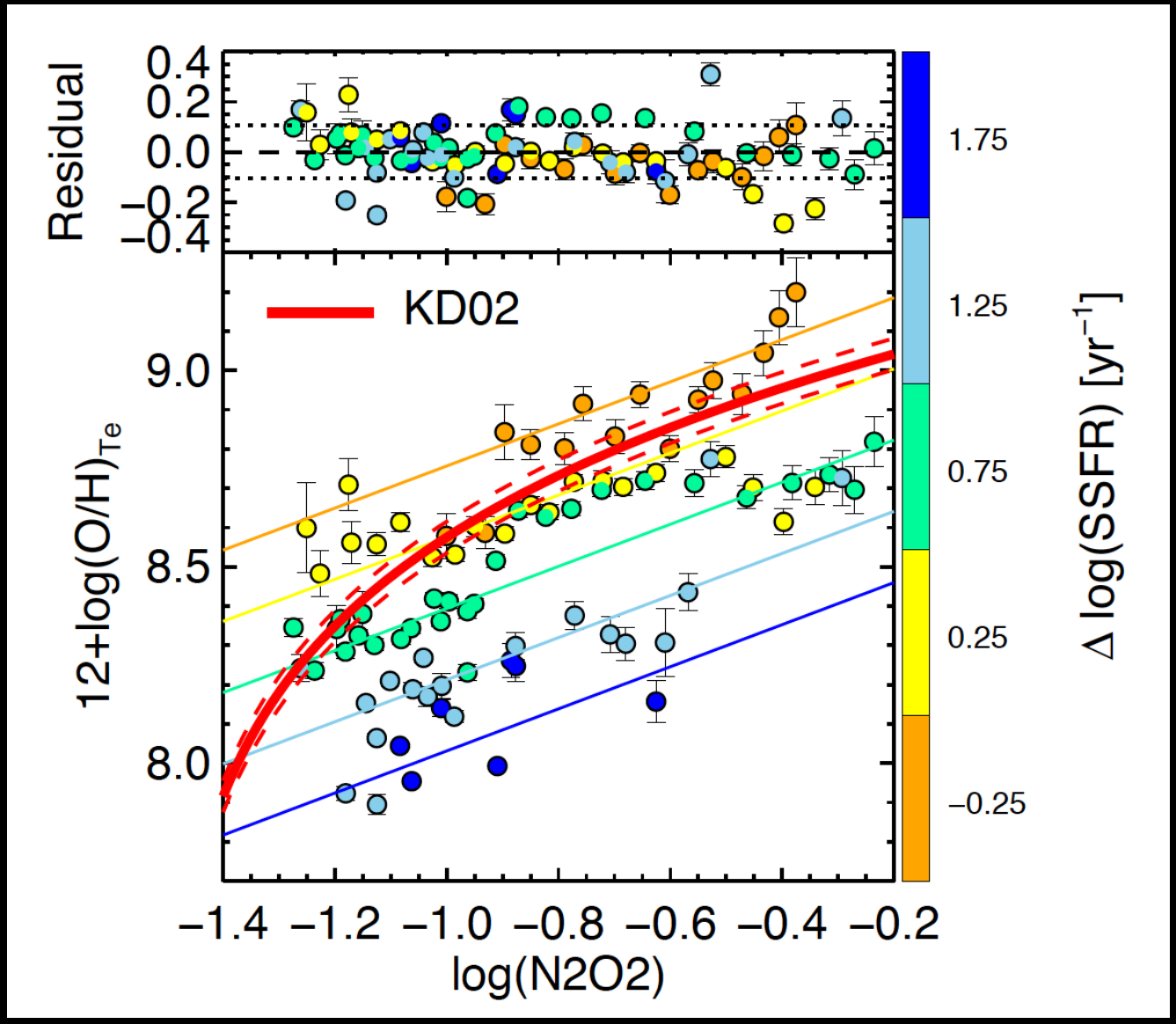
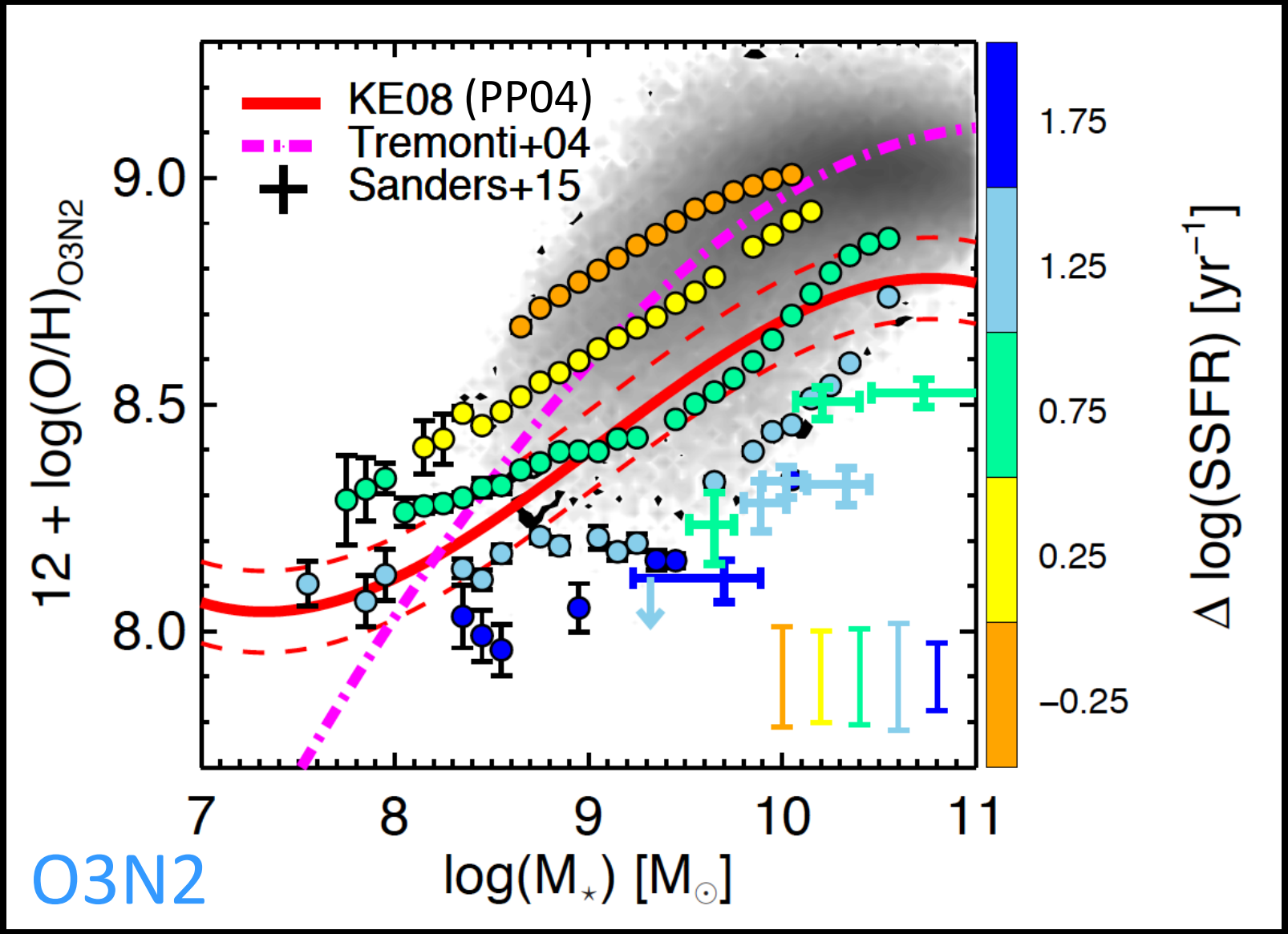
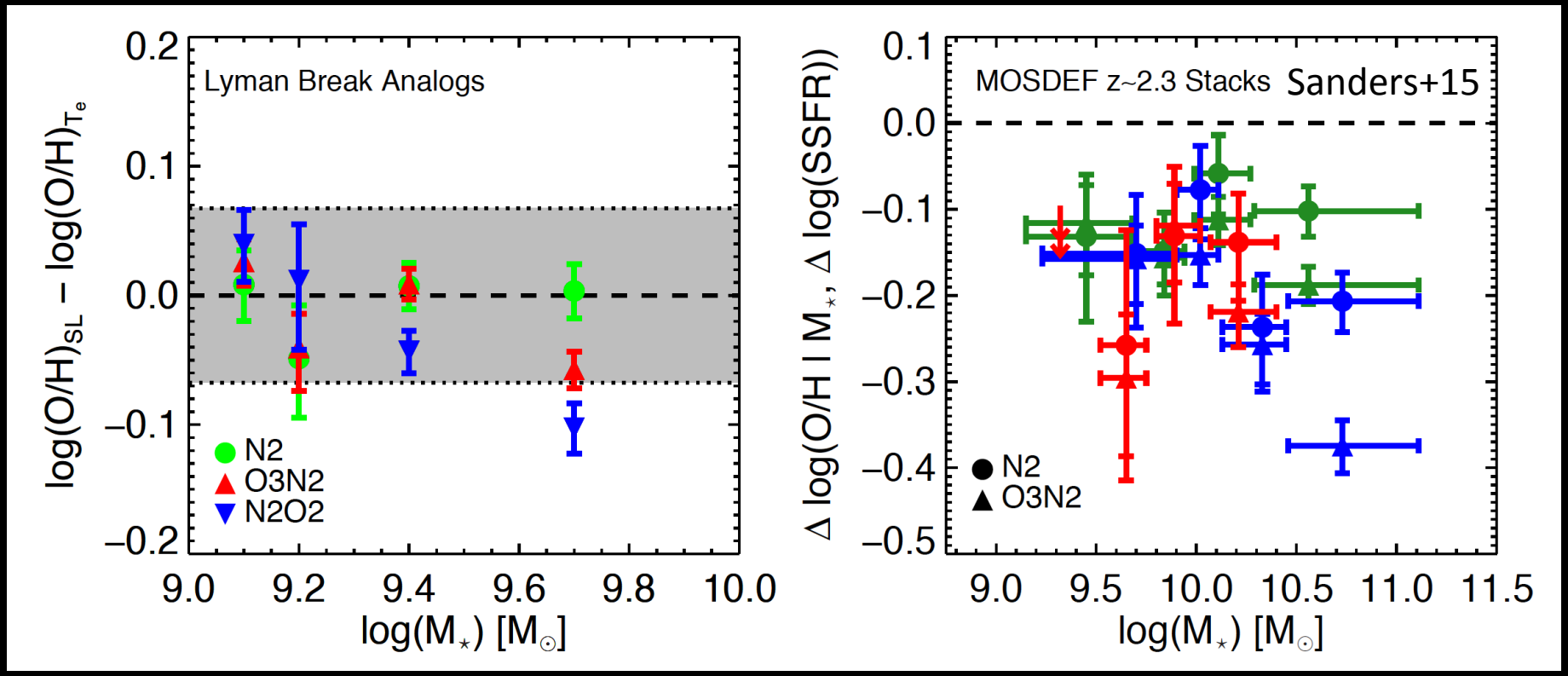


Brown, Martini, & Andrews (2015, in prep.)



Brown, Martini, & Andrews (2015, in prep.)

Evolution of the M-Z-SFR Relation

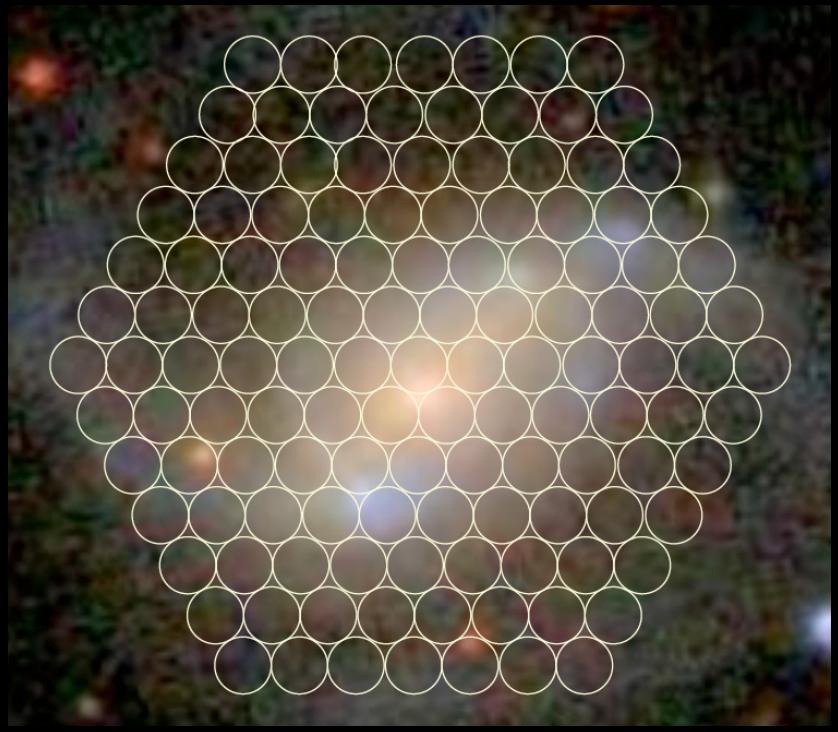


High-z galaxies are more metal-poor than local galaxies with similar Mstar and SFR.

Brown, Martini, & Andrews (2015, in prep.)

SDSS-I/II

SDSS-IV MaNGA



Images courtesy of M. Blanton

SDSS-I/II

SDSS-IV MaNGA

1400 galaxies observed (July 2015)

Images courtesy of M. Blanton

Conclusions

- Stacked SDSS galaxies to measure direct method metallicities with [OIII] & [OII]
- Direct Method Mass—Metallicity relation
  - extends over 3 dex in mass
  - strong SFR-dependence
- Recalibrated strong line diagnostics from direct method stacks as a function of SSFR
- Evolution of M-Z-SFR relation