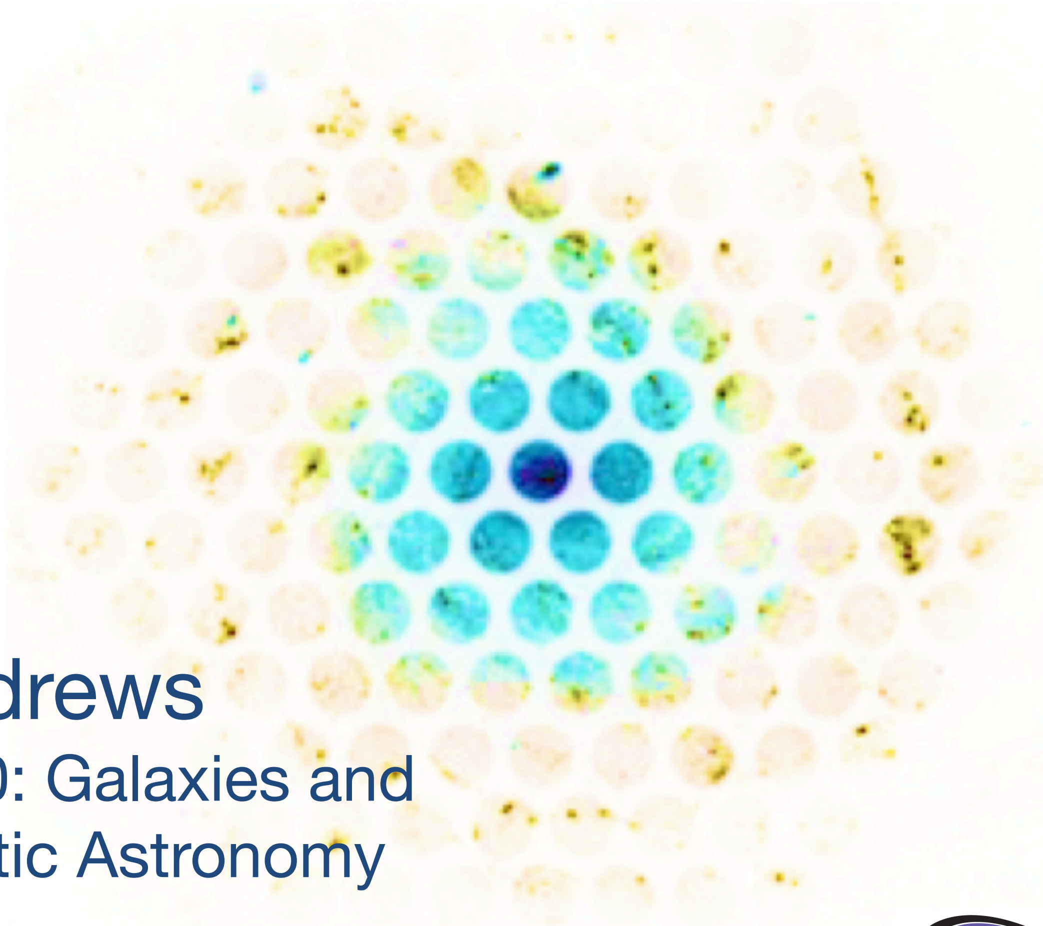
The Mass-Metallicity Relation

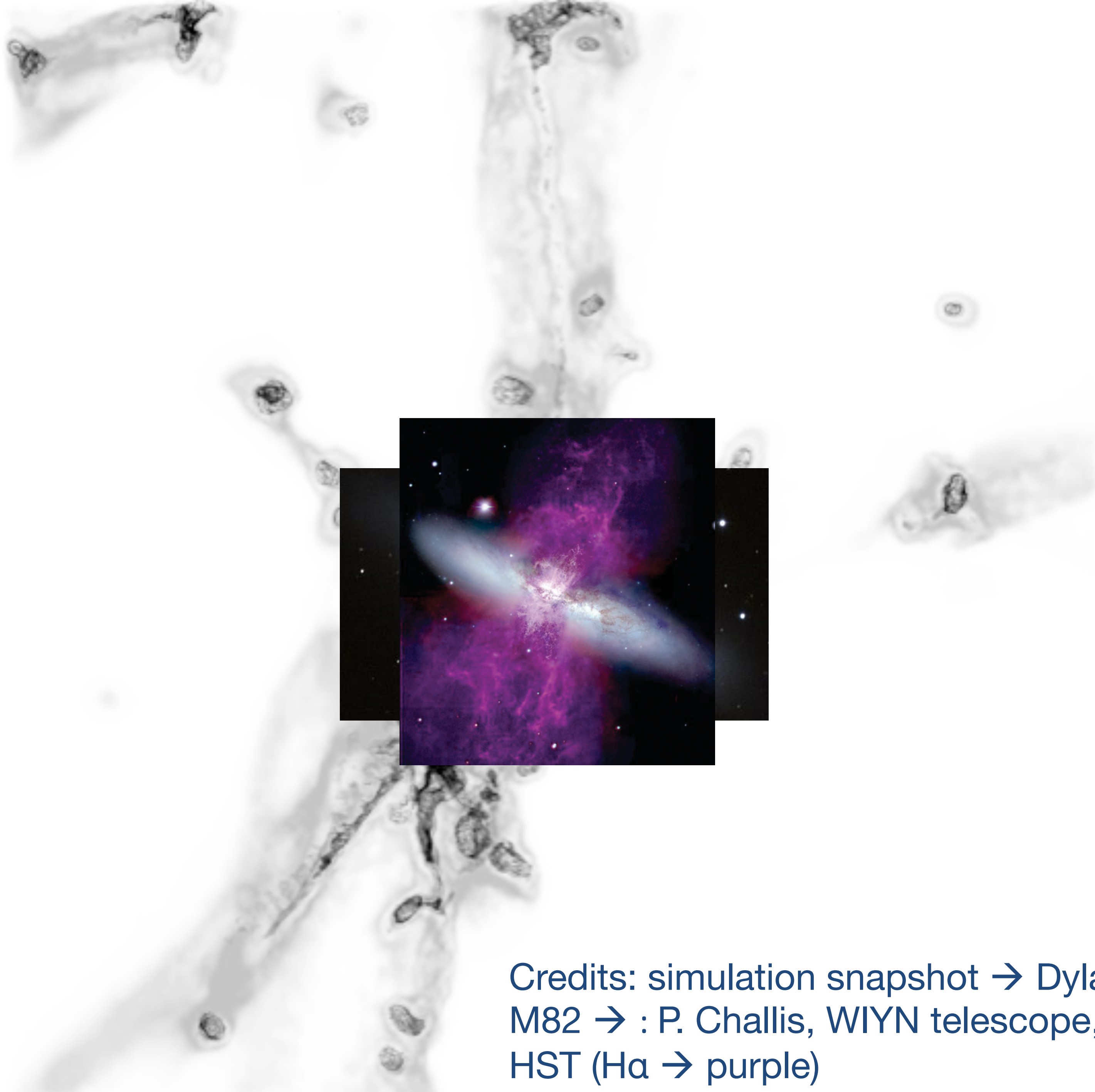


Brett Andrews

Astron 3580: Galaxies and Extra-galactic Astronomy

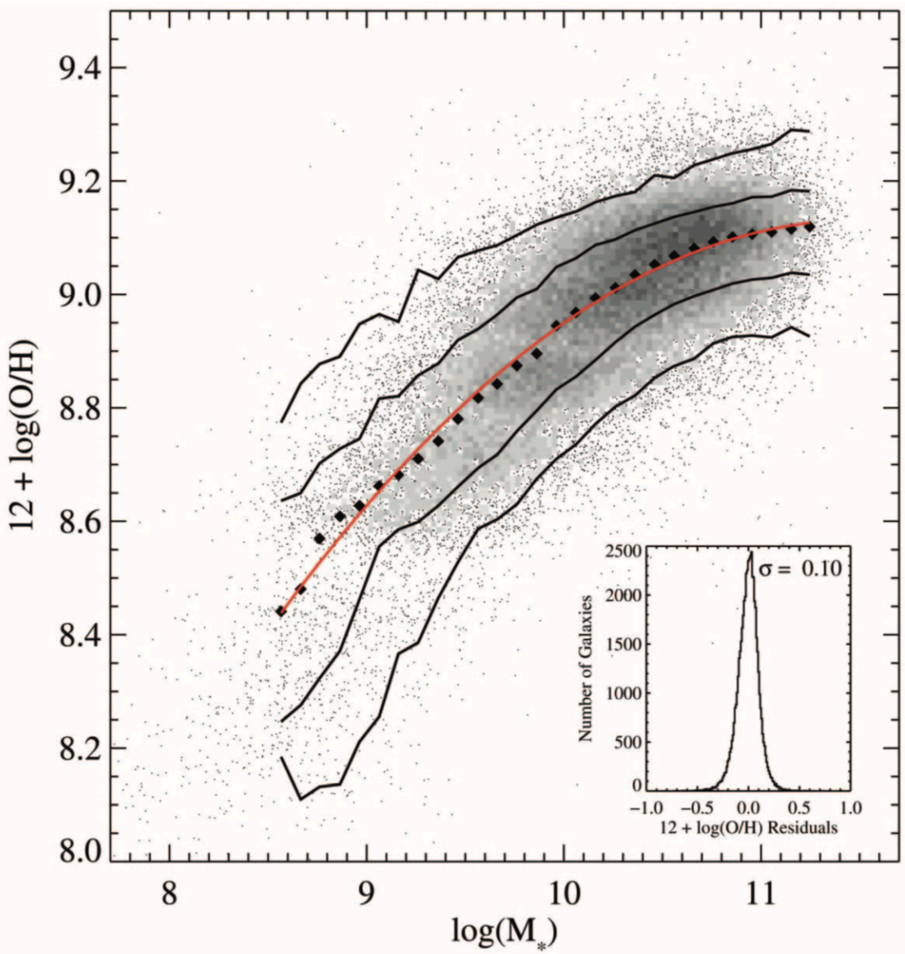
3.30.2018

University of Pittsburgh



Credits: simulation snapshot → Dylan Nelson
M82 → : P. Challis, WIYN telescope, &
HST (Hα → purple)

Mass-Metallicity Relation



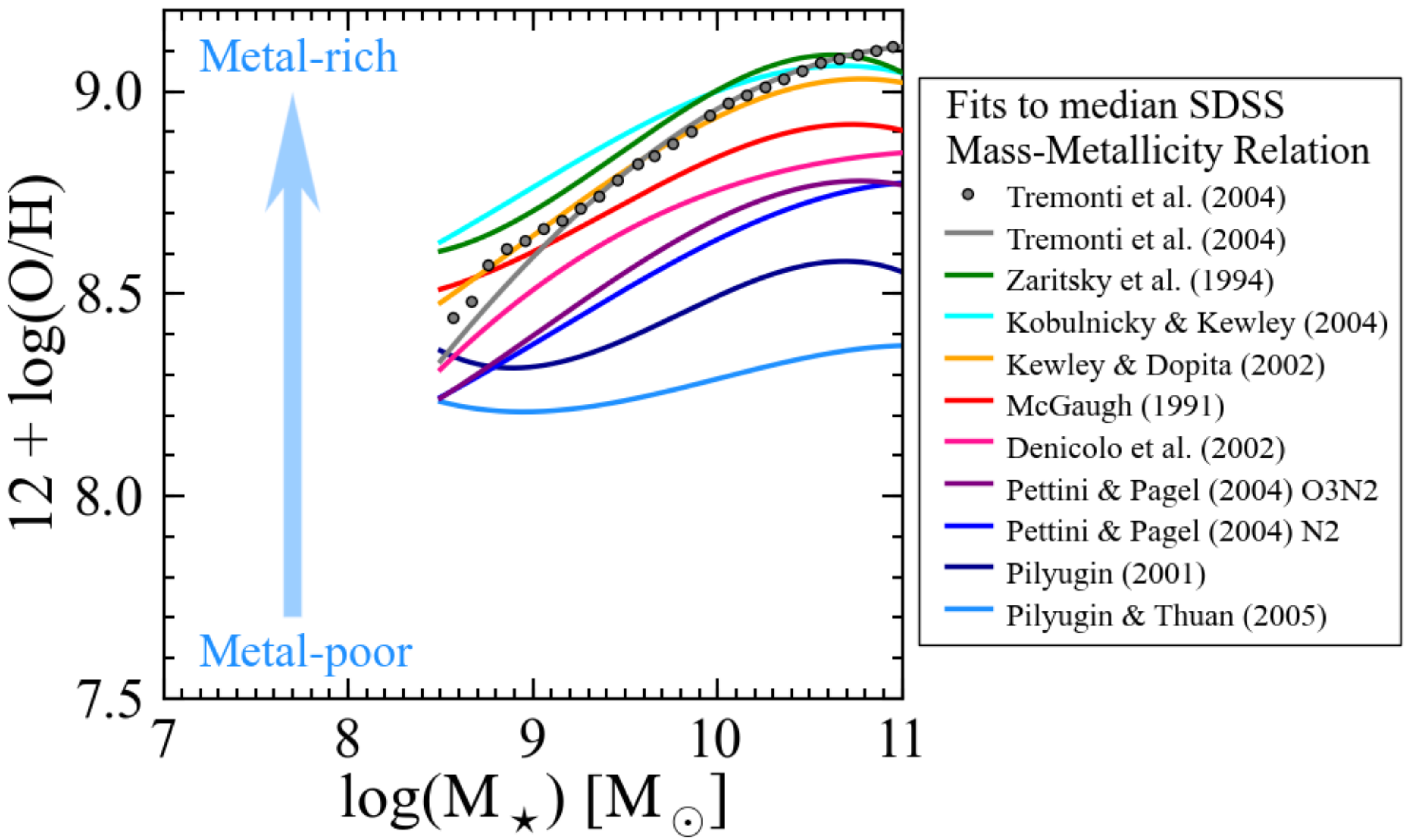
Tremonti et al. (2004)

Powerful observational constraint on galaxy formation models!

Features:

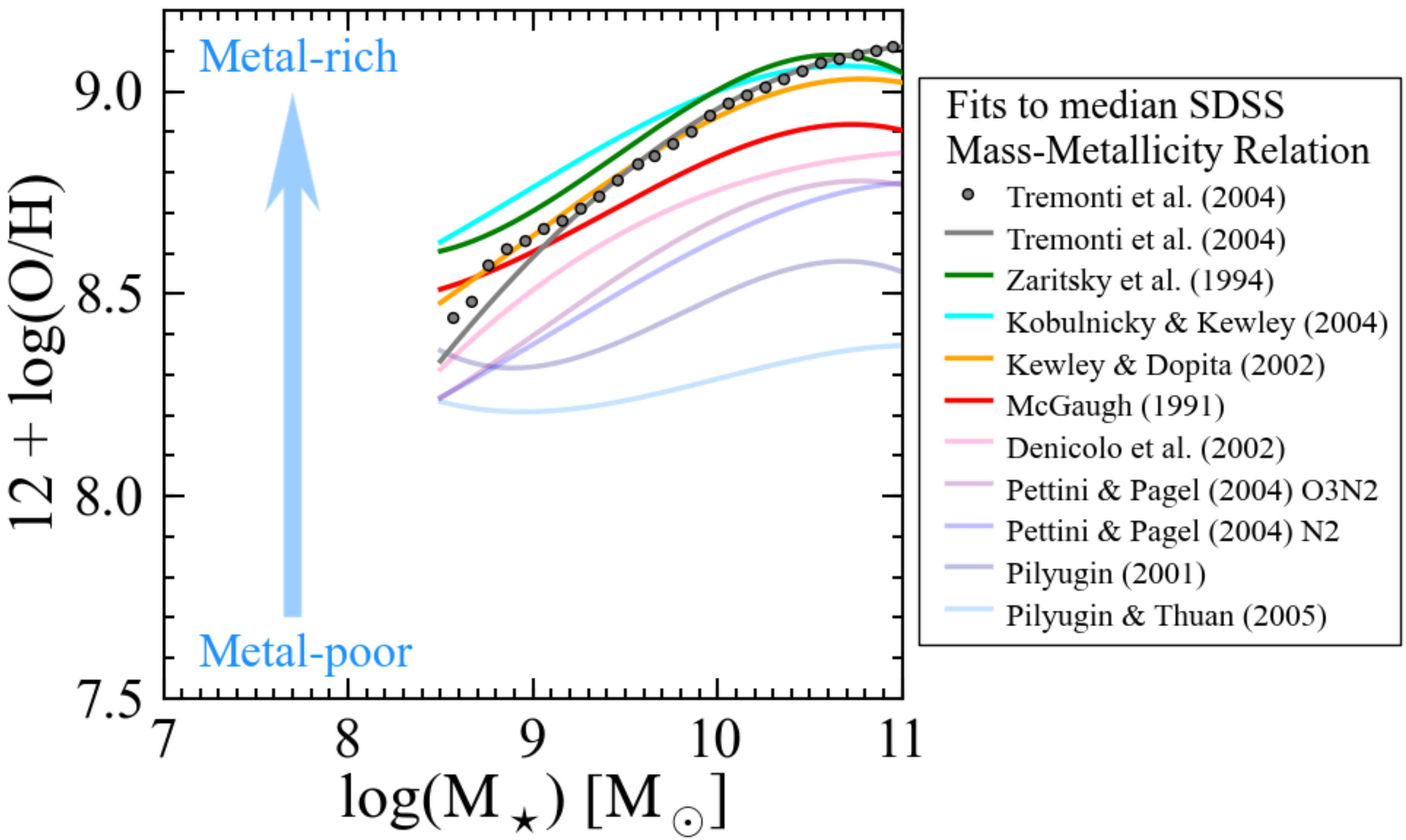
- normalization
- low mass slope
- turnover mass
- scatter
- evolution
- SFR-dependence

Strong line metallicities suffer from large systematic uncertainties.



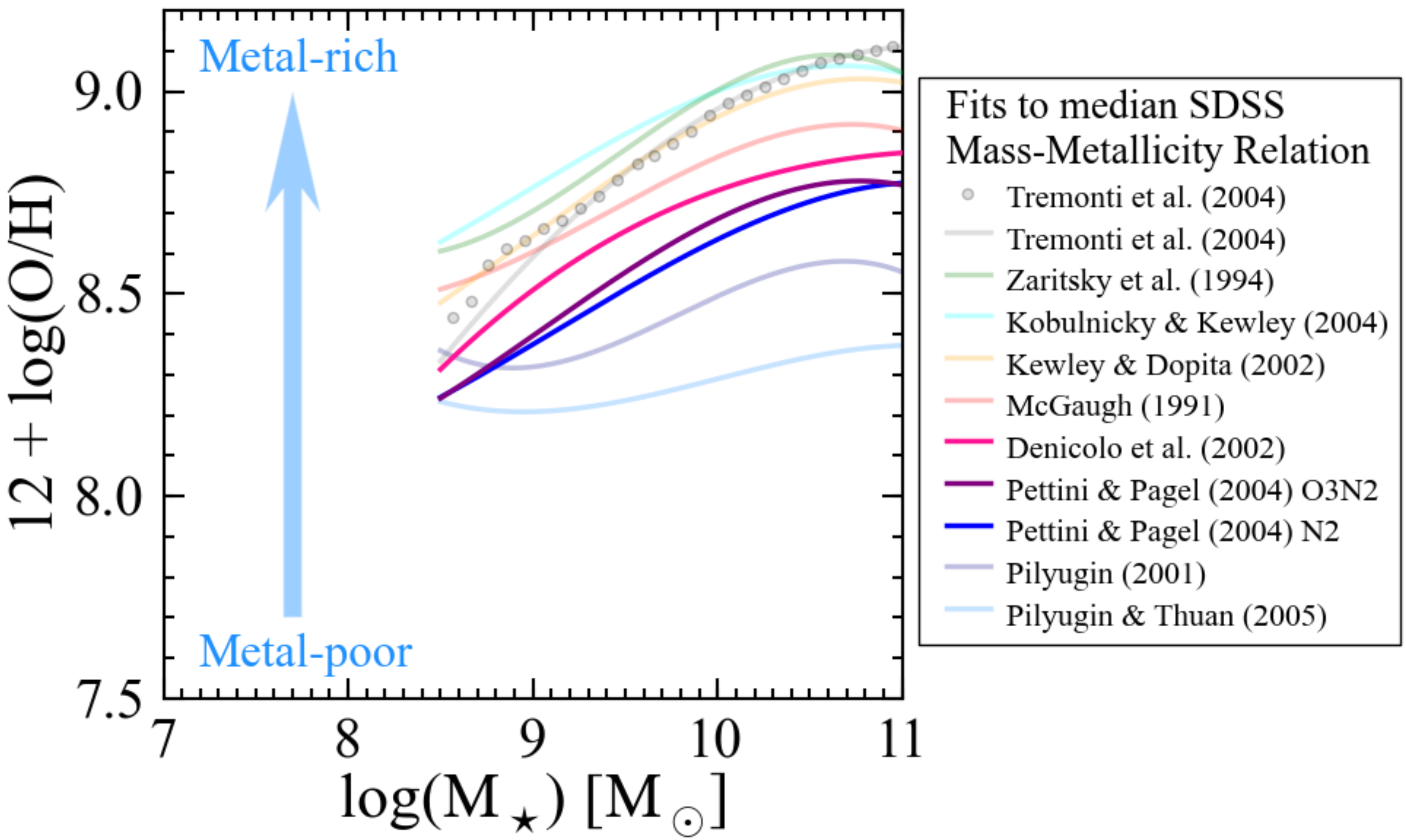
Fits from Kewley & Ellison (2008)

Theoretical Calibrations



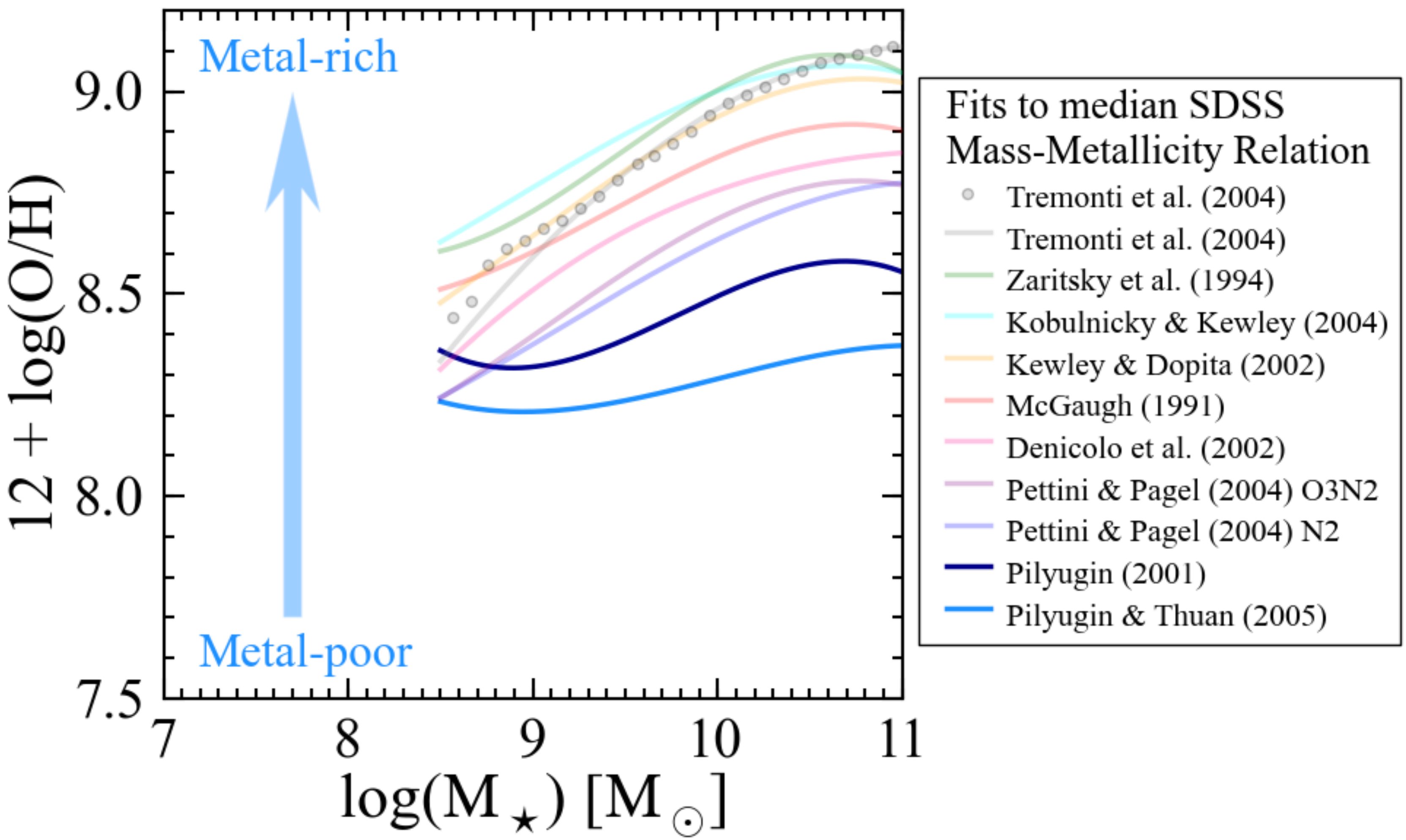
Fits from Kewley & Ellison (2008)

Semi-Empirical Calibrations



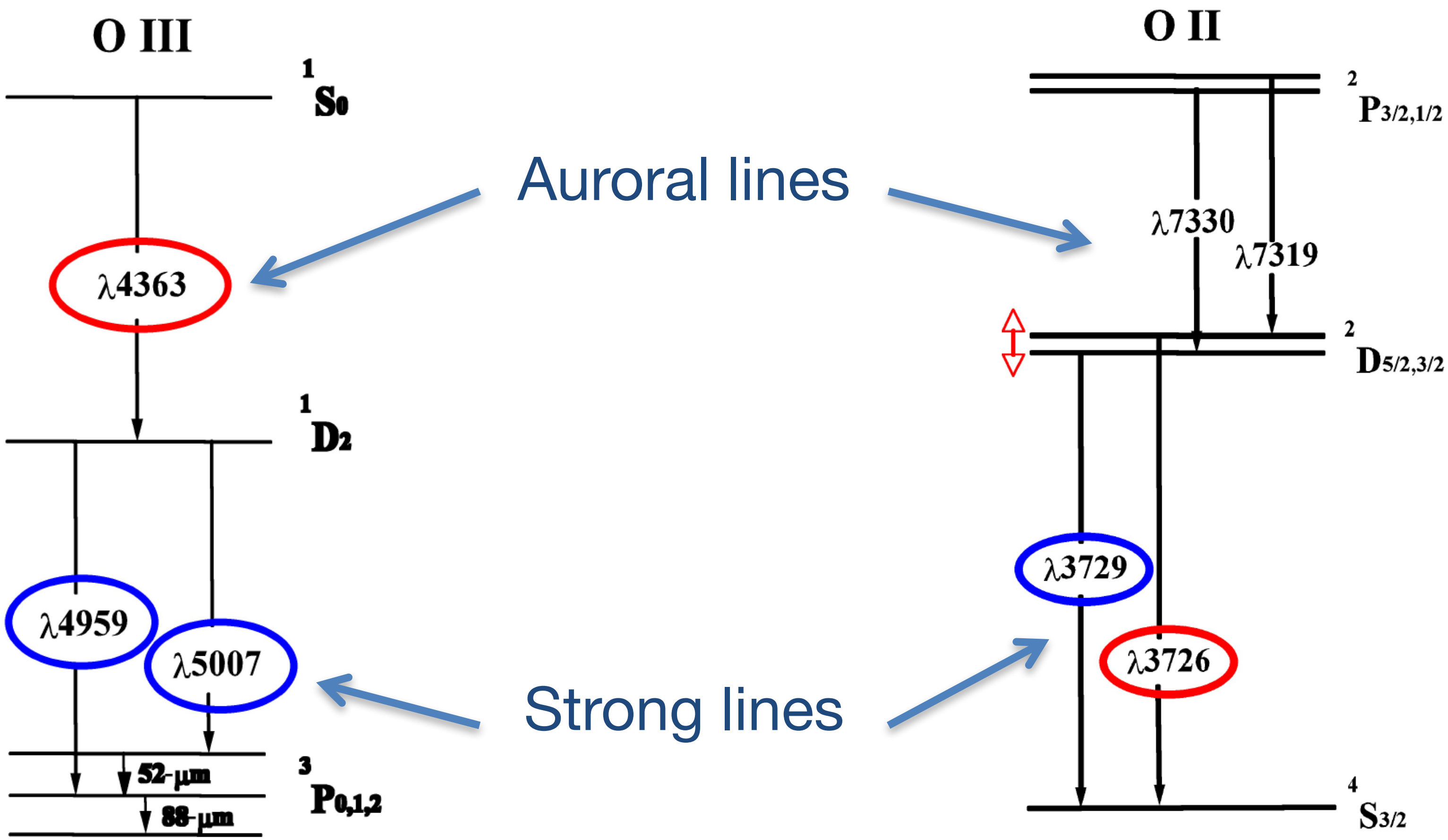
Fits from Kewley & Ellison (2008)

Empirical Calibrations



Fits from Kewley & Ellison (2008)

Auroral Lines: Temperature-sensitive



M. Westmoquette

Direct Method

limiting factor

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

$$\downarrow$$

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

$$\downarrow$$

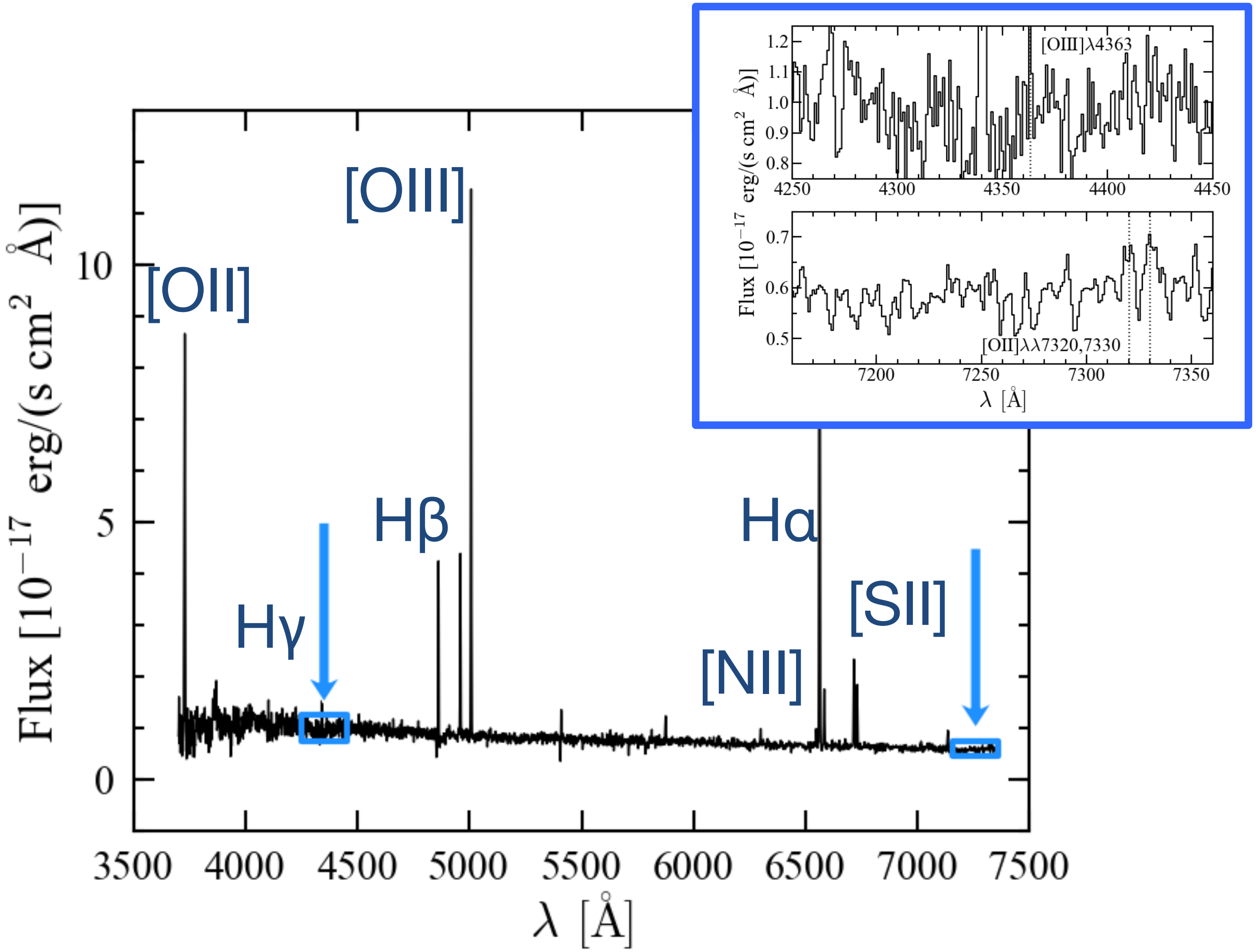
$$\frac{\mathrm{O}^{++}}{\mathrm{H}}$$

$$\downarrow$$

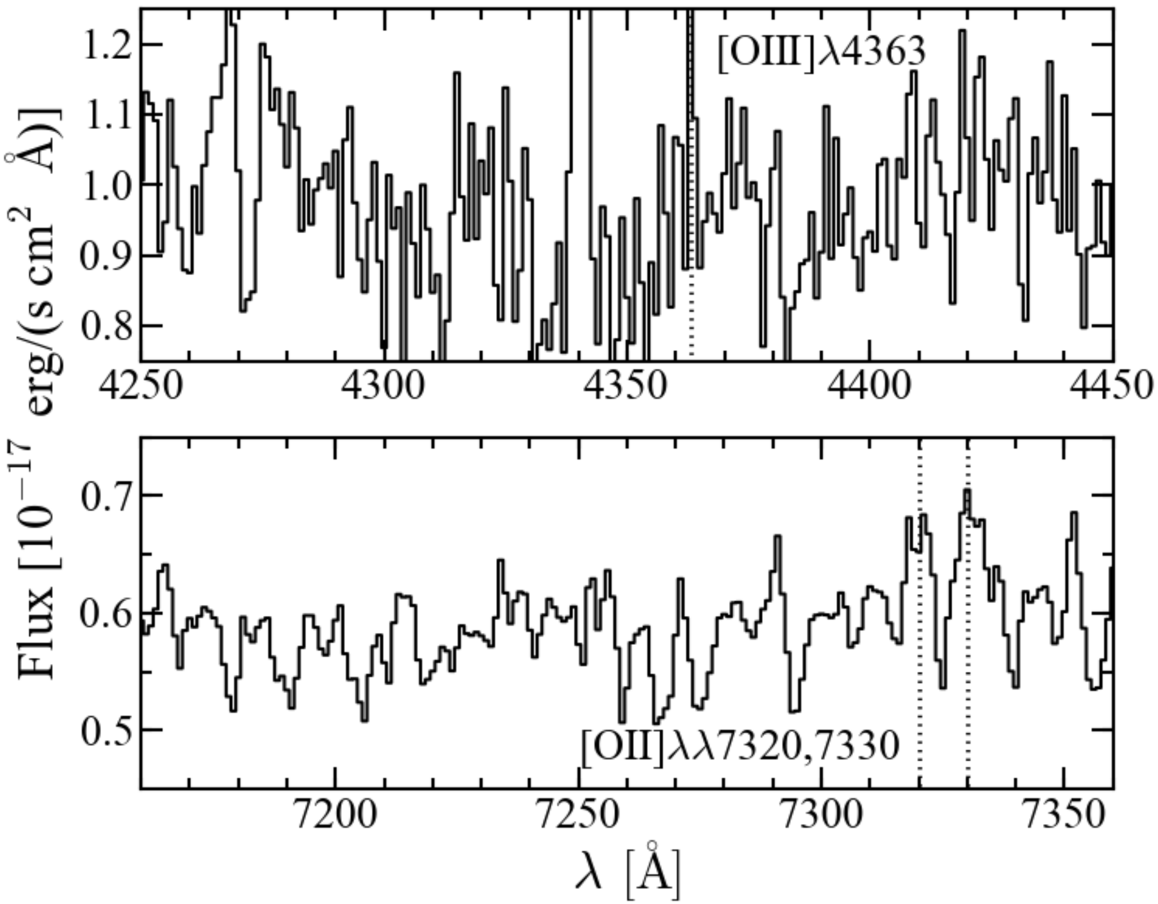
Metallicity: $$\frac{\mathrm{O}}{\mathrm{H}} = \frac{\mathrm{O}^{+}}{\mathrm{H}} + \frac{\mathrm{O}^{++}}{\mathrm{H}}$$

(Repeat for O+)

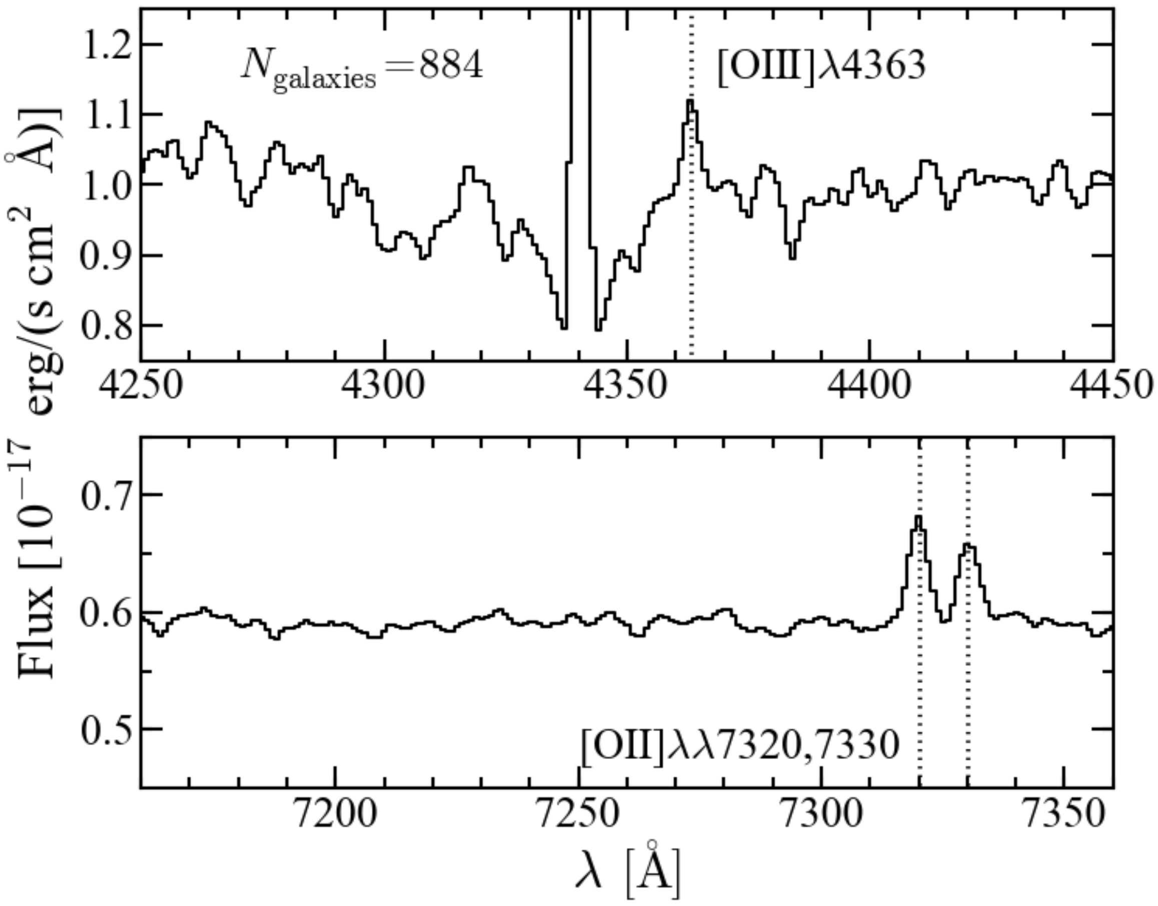
Auroral lines are very weak



Auroral Lines of a Single Galaxy

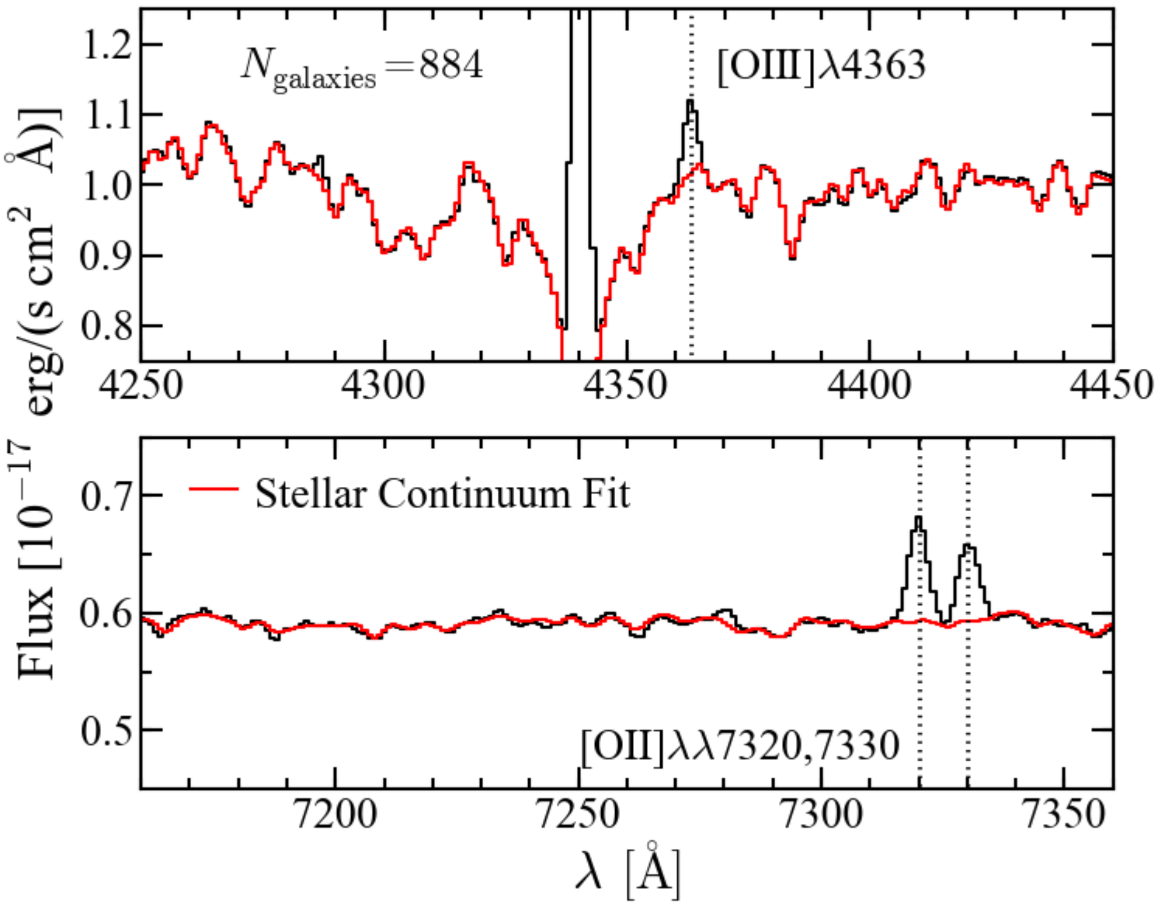


Stack of Galaxies



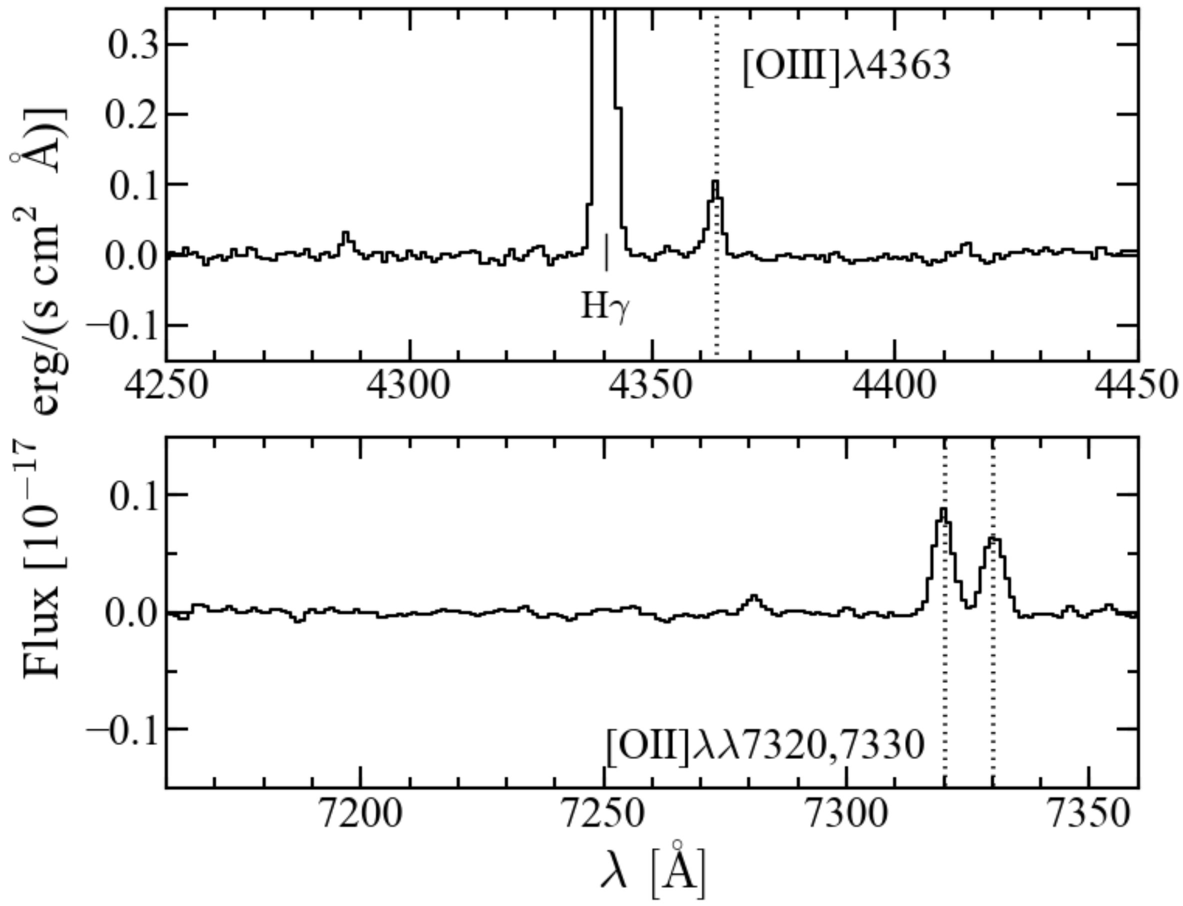
stellar absorption lines

Fit the Underlying Stellar Spectrum

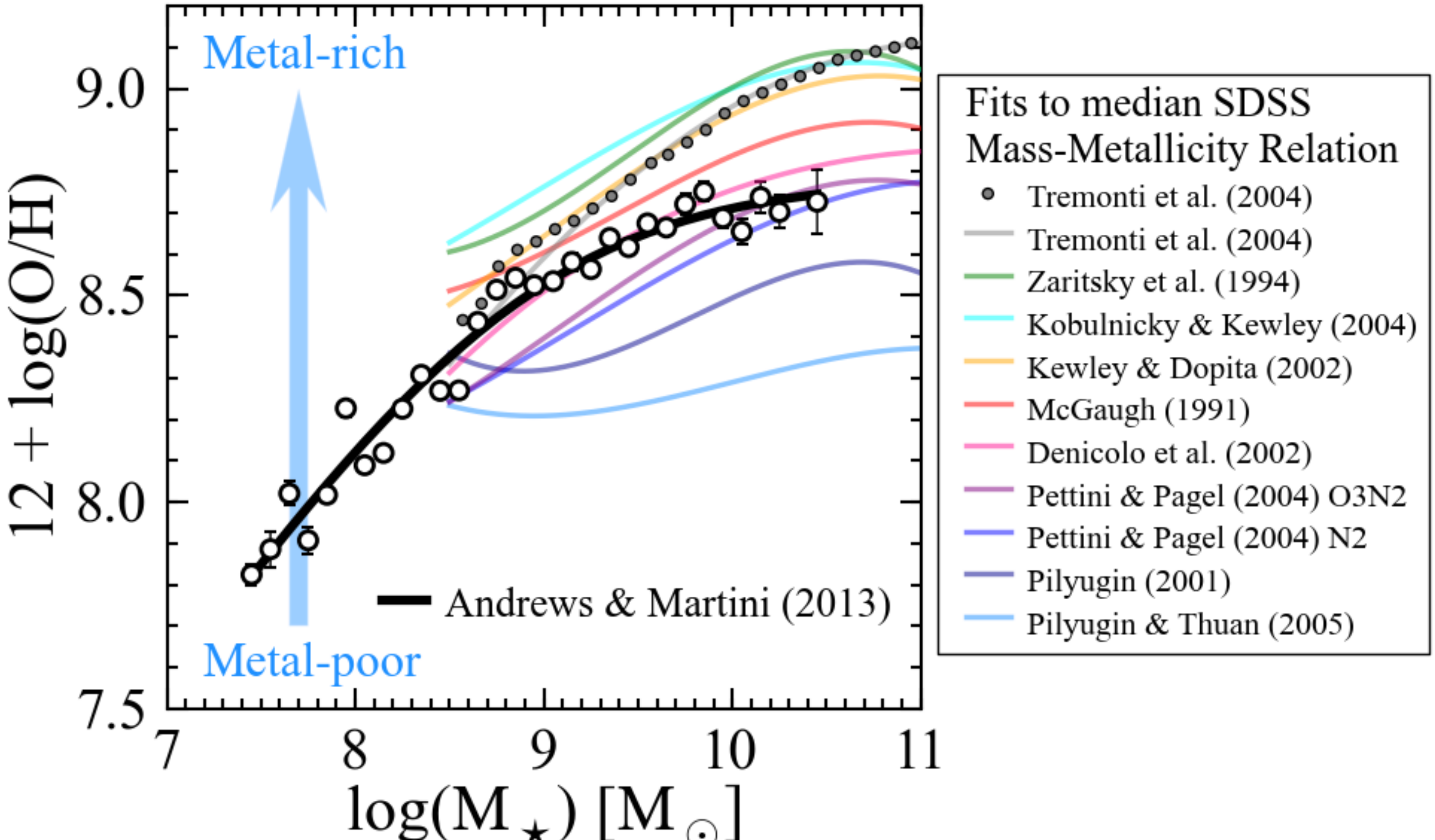


Stellar continuum fit with STARLIGHT stellar synthesis code (Cid Fernandes et al. 2005)

Final Spectrum

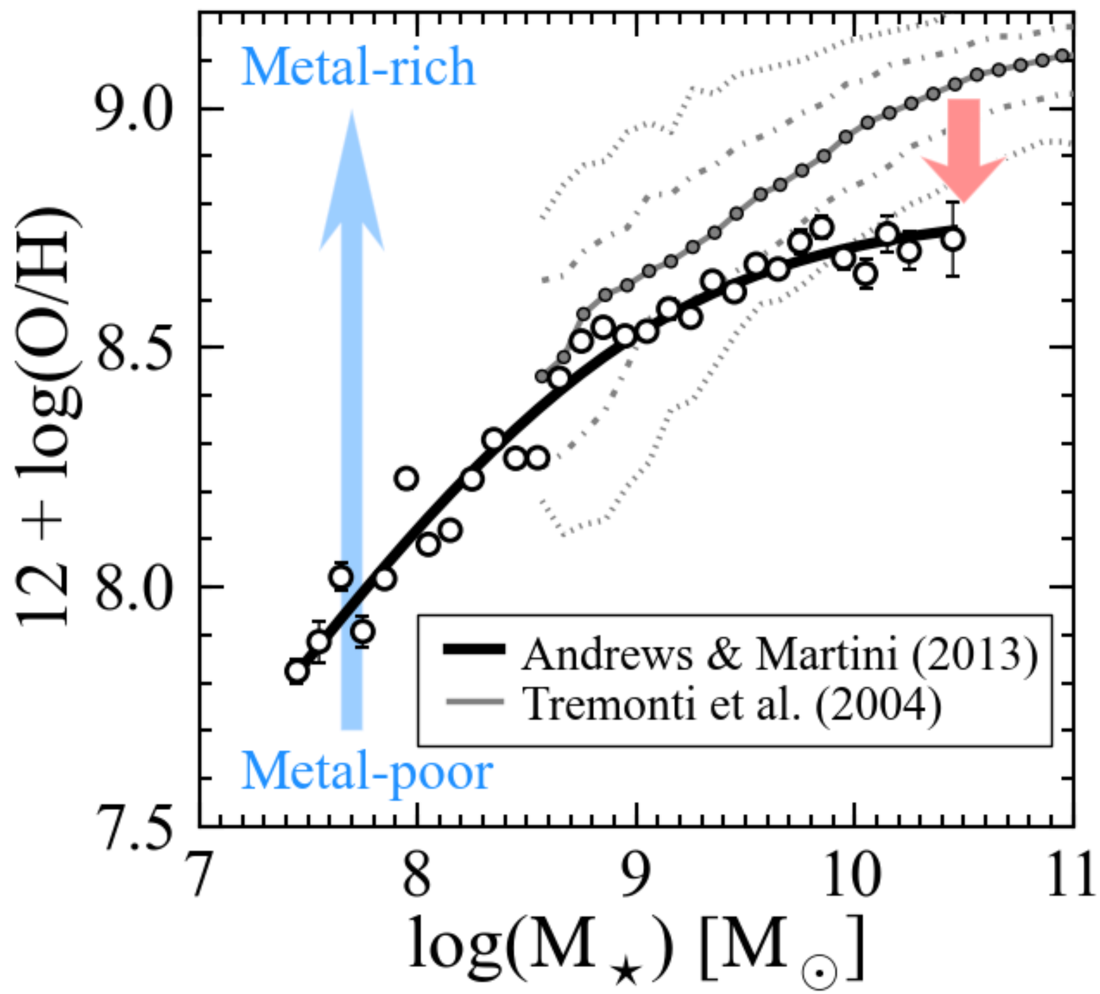


Direct Method Mass—Metallicity Relation



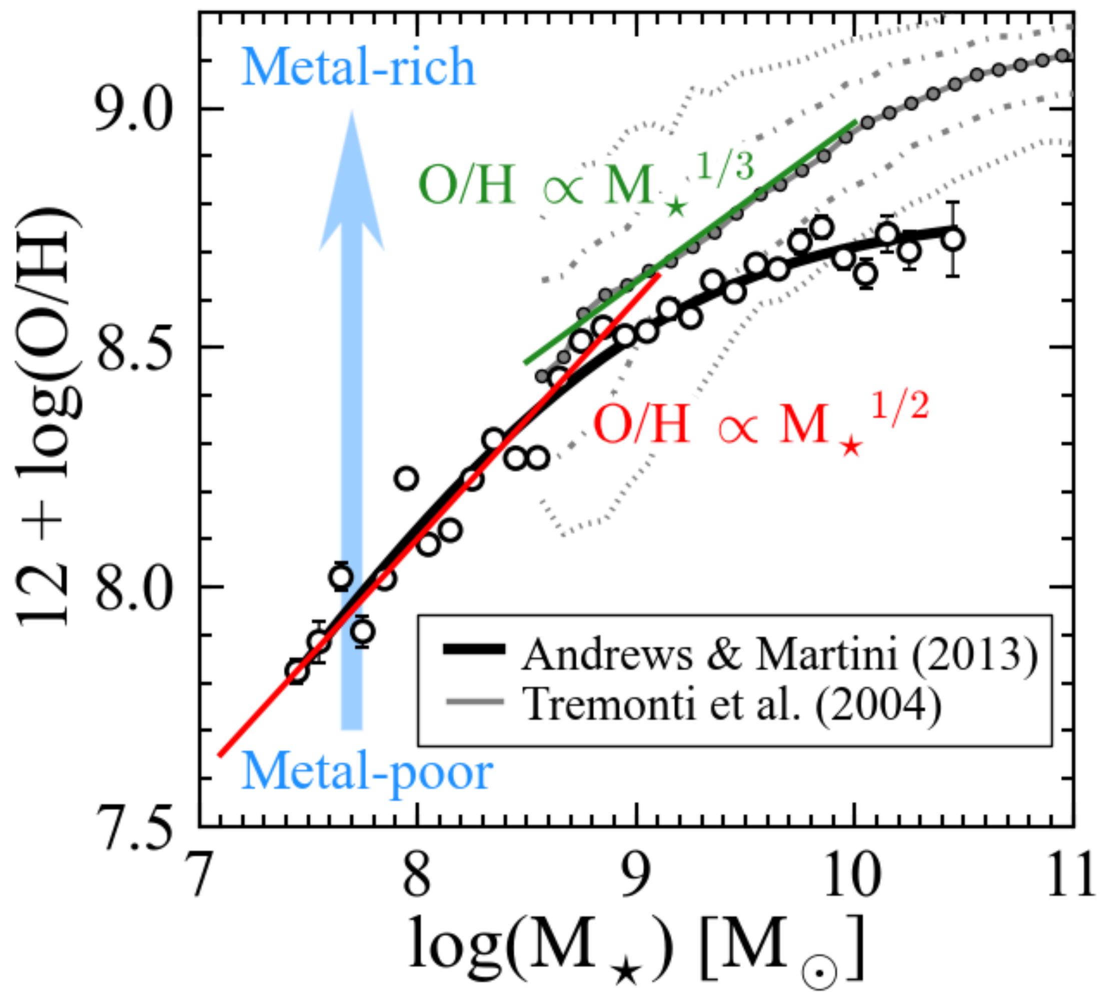
Fits from Kewley & Ellison (2008)

Normalization



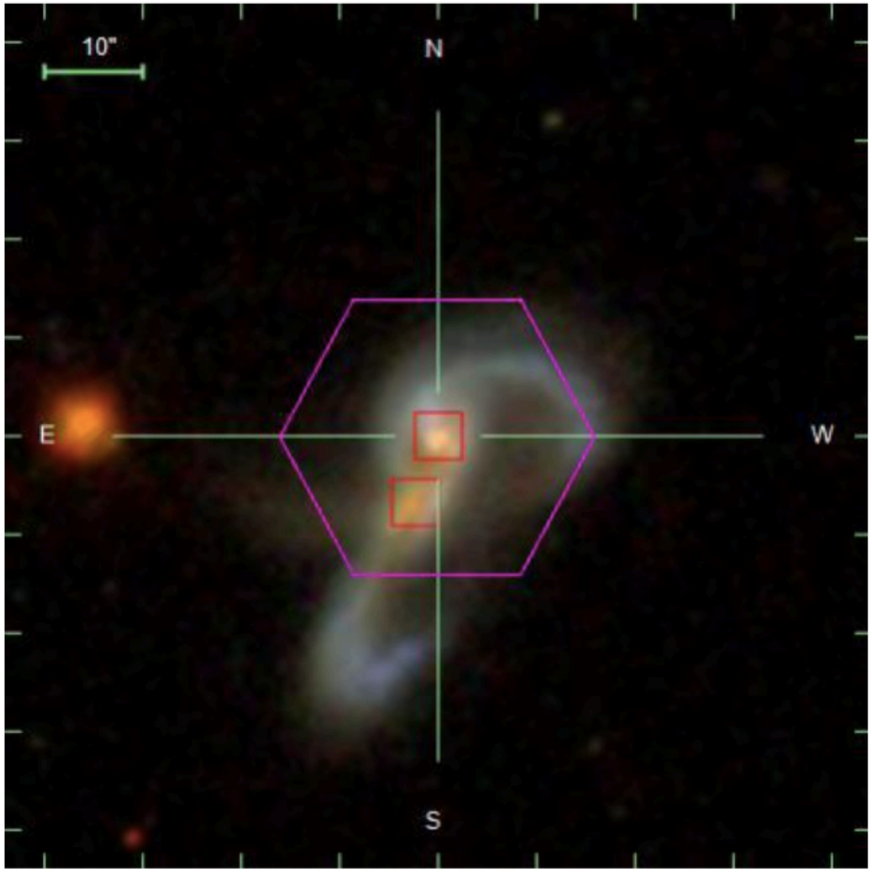
Galactic winds are efficient at ejecting metals…

Low Mass Slope

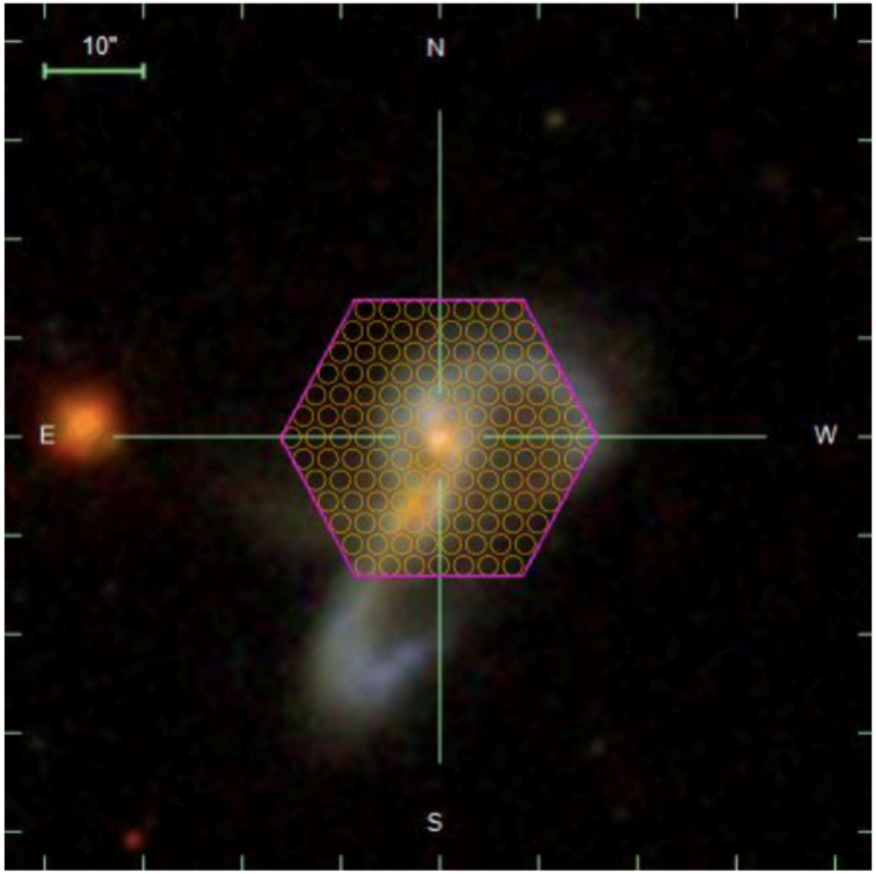


…especially in low mass galaxies.

Previous SDSS Surveys



MaNGA

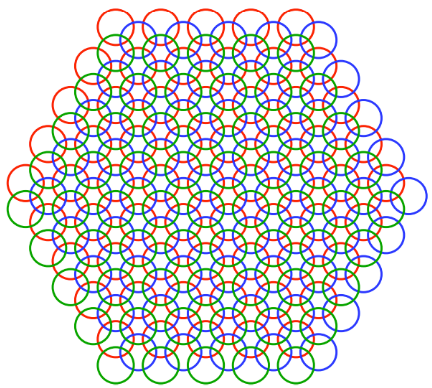


Credit: Mike Blanton

MaNGA Data Reduction

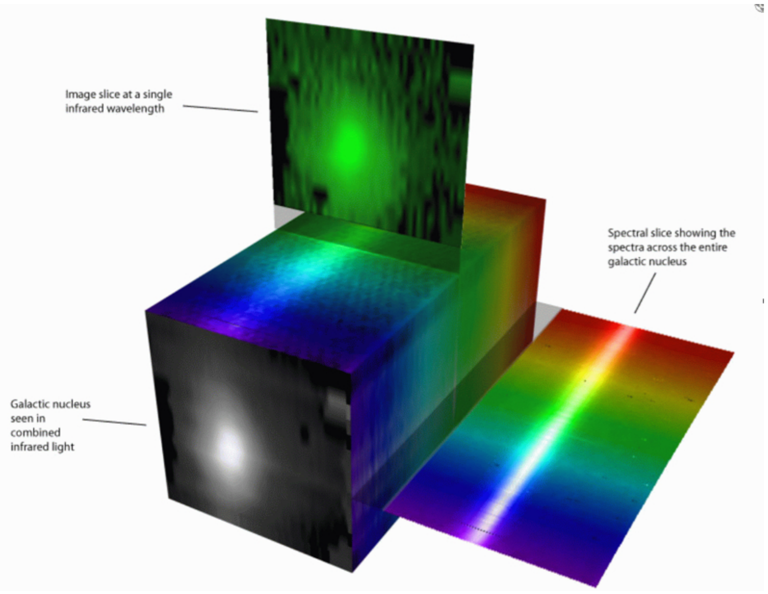
Row-Stacked Spectra

(spectrum from each fiber at each dither position)



Law et al. (2015)

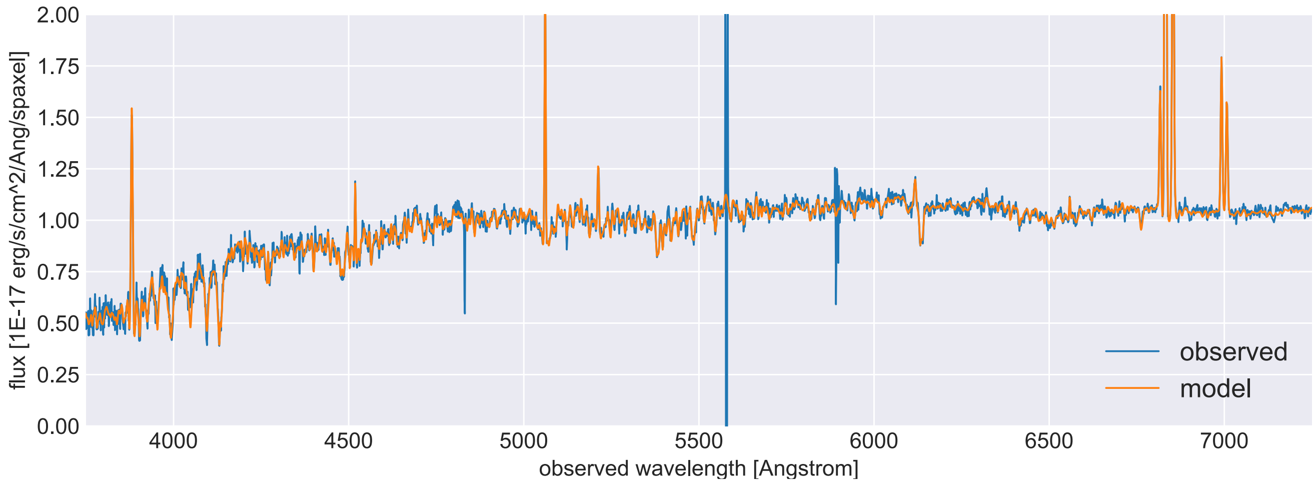
Cubes



Credit: Stephen Todd (ROE) & Douglas Pierce-Price (JAC)

MaNGA Data Analysis

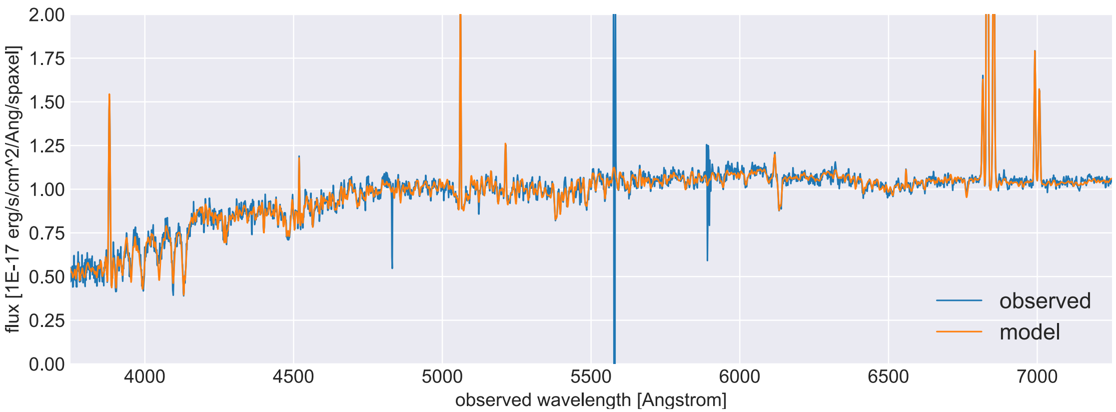
1. Fit stellar continuum
2. Fit emission lines
3. Measure spectral indices



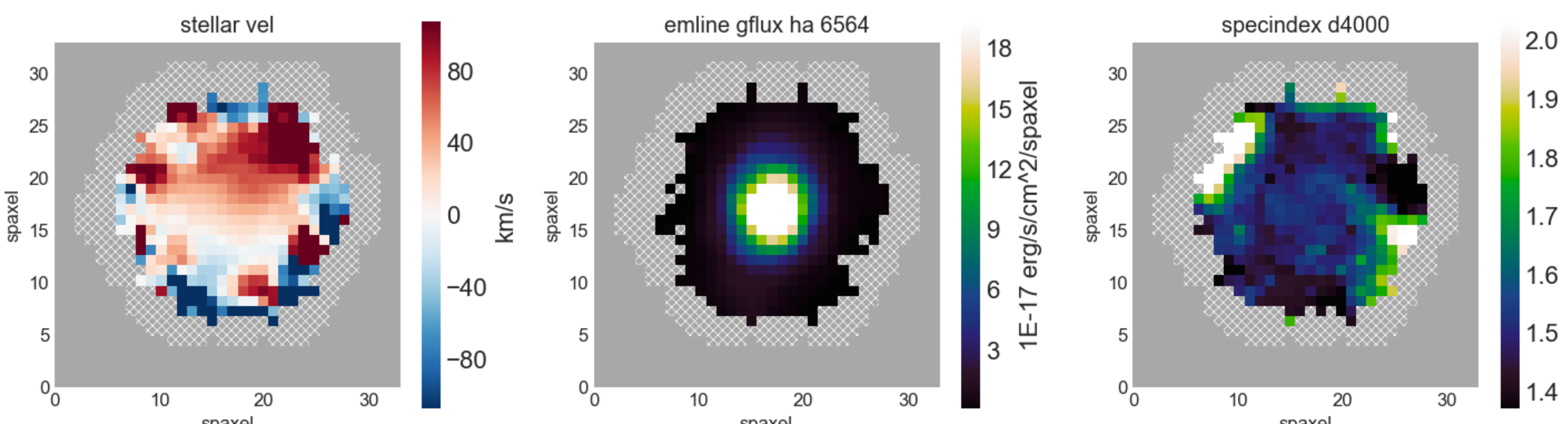
Westfall et al. (in prep.)

MaNGA Analysis Products

Model Cubes

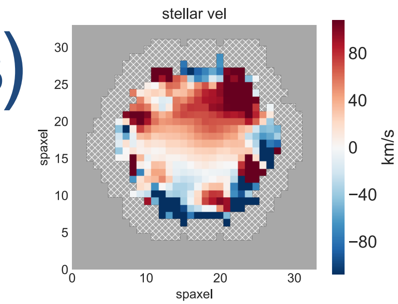


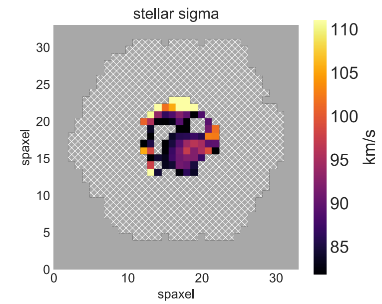
Maps

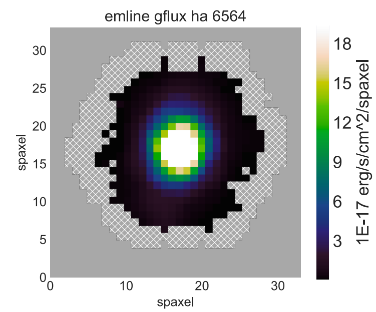


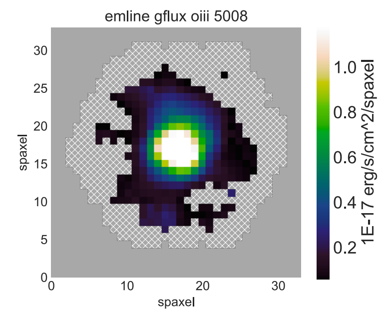
Analysis Properties

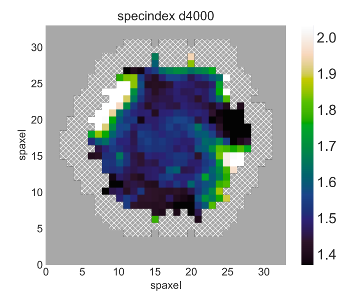
- Kinematics (stellar & gas)
  - velocity & sigma
- Emission line fluxes
  - Hα–Hε, HeI, HeII, [OI], [OII], [OIII], [NII], [SII], [SIII]
- Spectral Indices
  - D4000





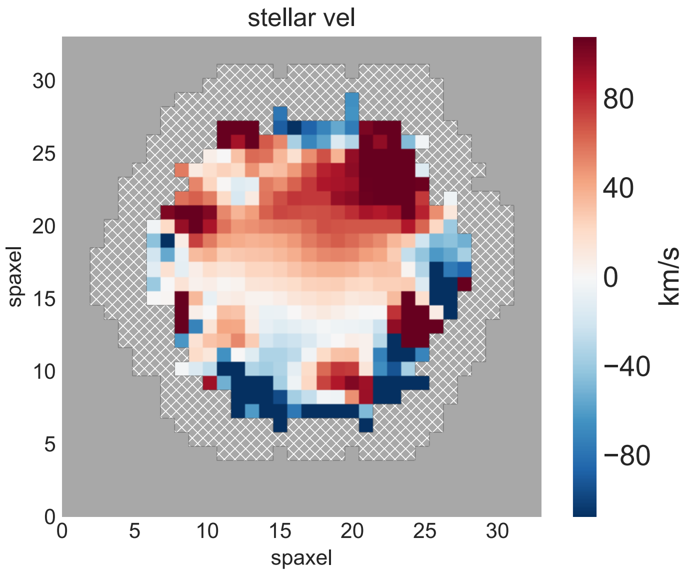




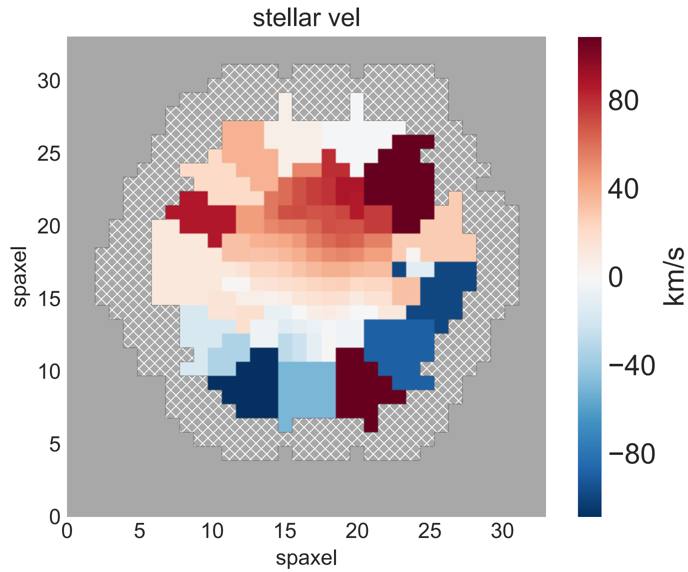


Bin Types

SPX (unbinned)



VOR10 (Voronoi binning to S/N = 10)

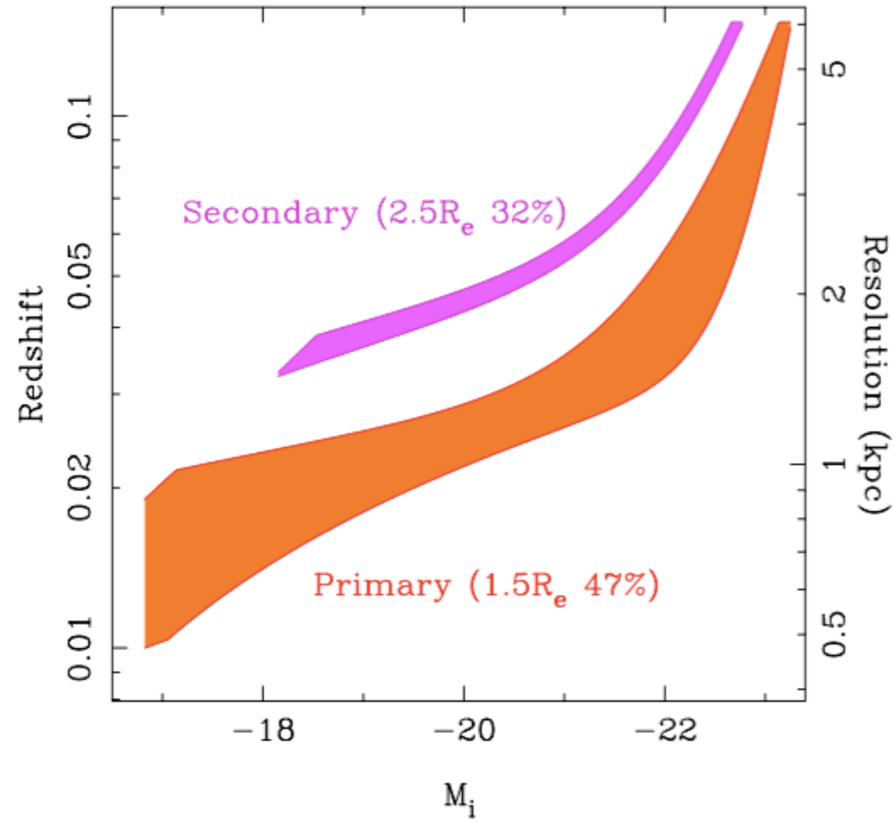


MaNGA Science Drivers

1. How does gas accretion drive growth?
2. How do mergers, stellar accretion, and instabilities build spheroidals?
3. What quenches star formation? Does is it depend on environment?
4. How is angular momentum distributed and transferred during formation?
5. How do various mass components assemble and influence one another?

MaNGA Sample Design

- $M_\star > 10^9\ M_\odot$
- Flat distribution in $M_\star$
- Two main subsamples: 1.5 and 2.5 $R_{effective}$



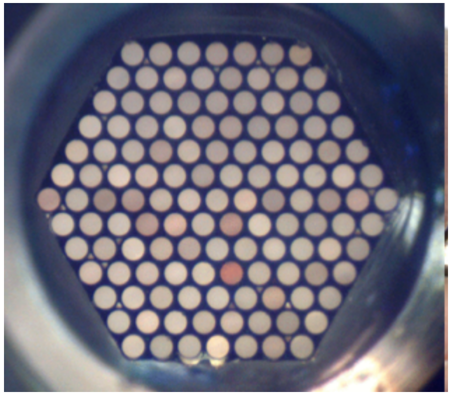
Bundy et al. (2015)

- Ancillary programs:
  - 5-10% of bundles

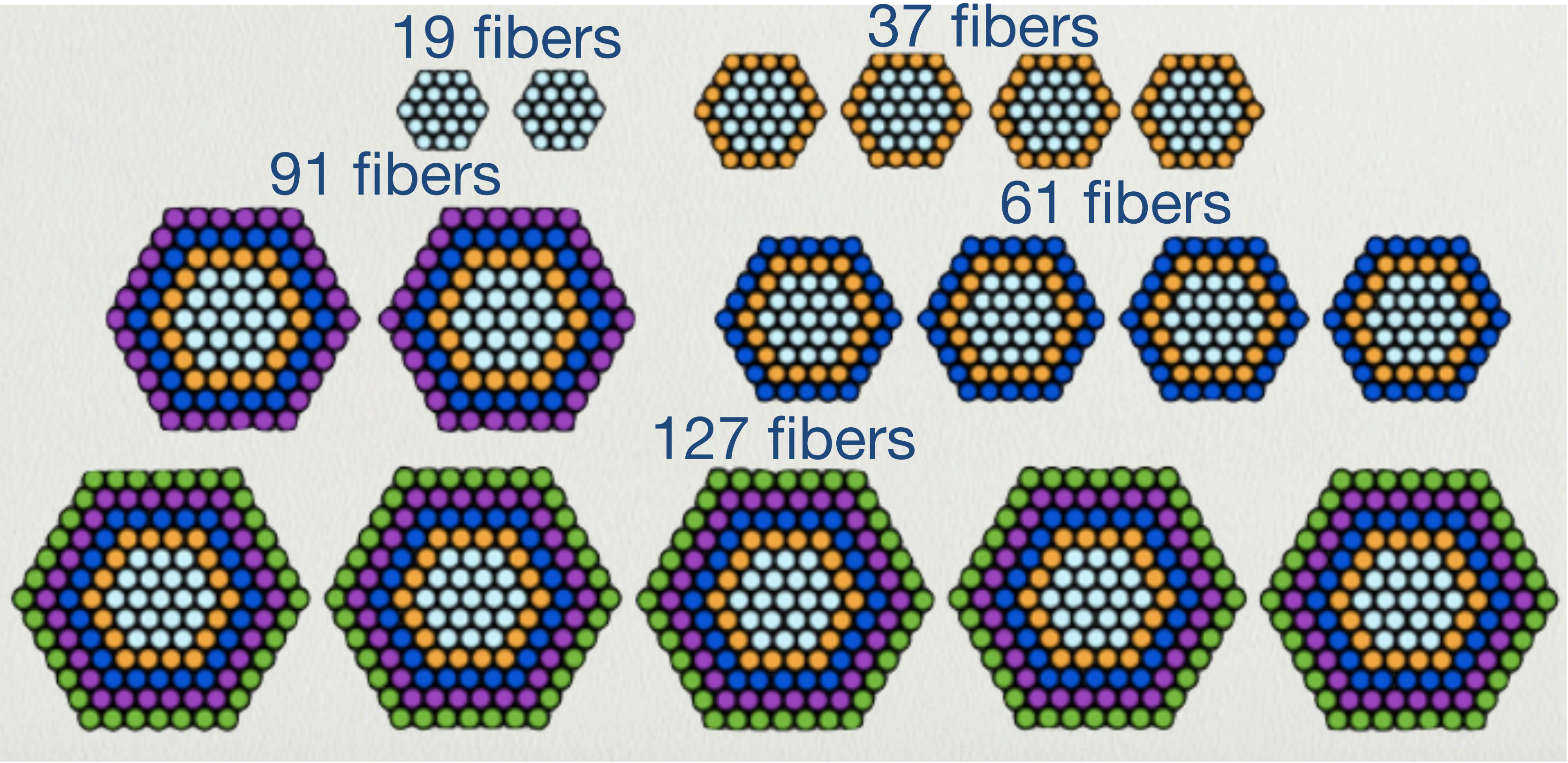
MaNGA Overview

- **MaNGA**: Mapping Nearby Galaxies at Apache Point Observatory
- One of three main sub-surveys of SDSS-IV (2014-2020)
- PI: **Kevin Bundy**. Over 160 members at 50+ institutions.

- Integral Field Unit (IFU) observations of 10,000 nearby galaxies
- $z = 0.01 — 0.15$
- $\lambda \sim 3{,}600 — 10{,}300$ Å
- $R \sim 1400 — 2600$ (115 — 215 km/s)
- Spatial resolution: 1.3 — 5.1 kpc

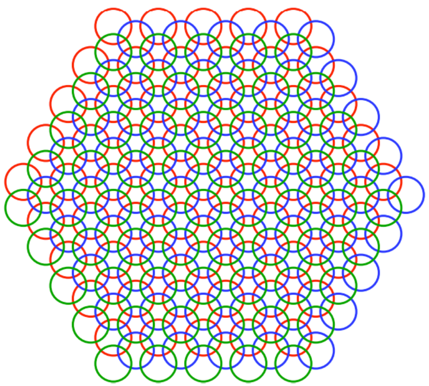


IFU Sizes

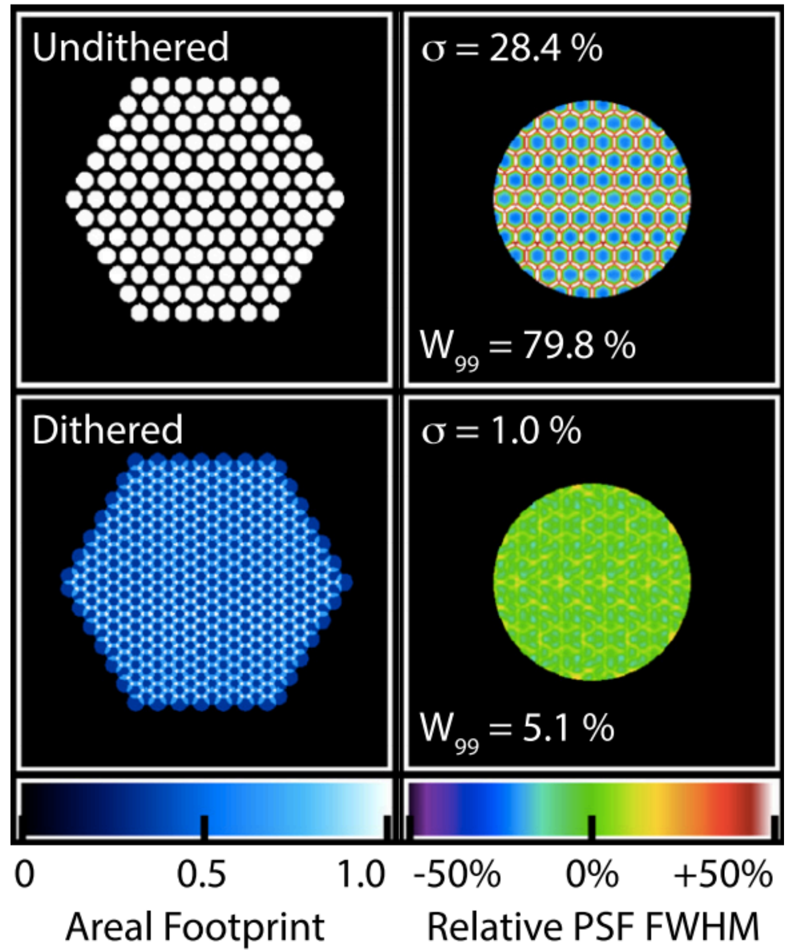


Credit: Kevin Bundy

Dithering



Law et al. (2015)



MPL-6

- **~4750 galaxies**
- Extensive testing of the stellar kinematics
- Improved emission-line fitting
  - tied kinematics and tied fluxes of doublets
- Hybrid binning scheme
  - S/N > 10 for stellar kinematics and individual spaxels for emission lines
- Extended set of spectral index measurements