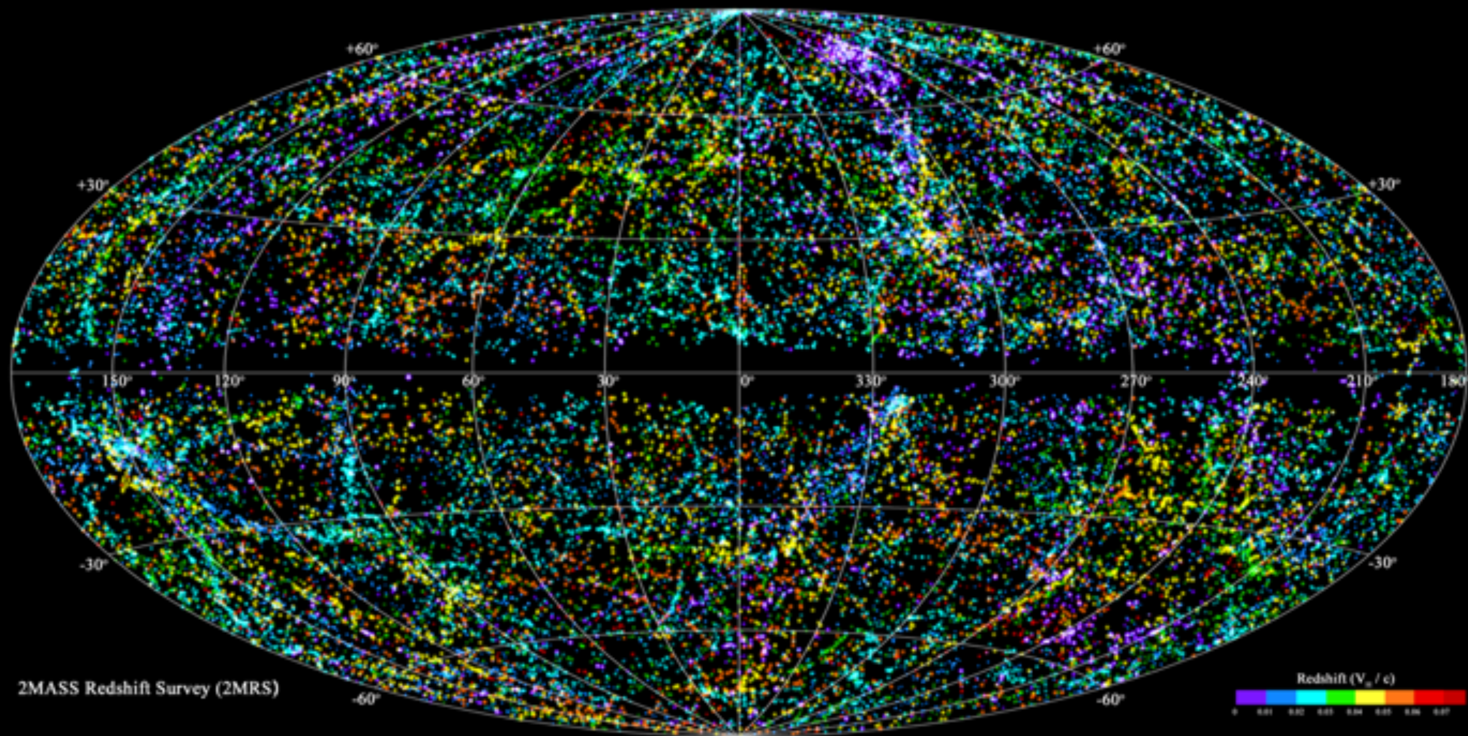
A Uniformly Selected, All-Sky Optical AGN Catalog



Ingyin Zaw (New York University Abu Dhabi)

Supermassive Black Holes Environment & Evolution

Corfu, June 19, 2019

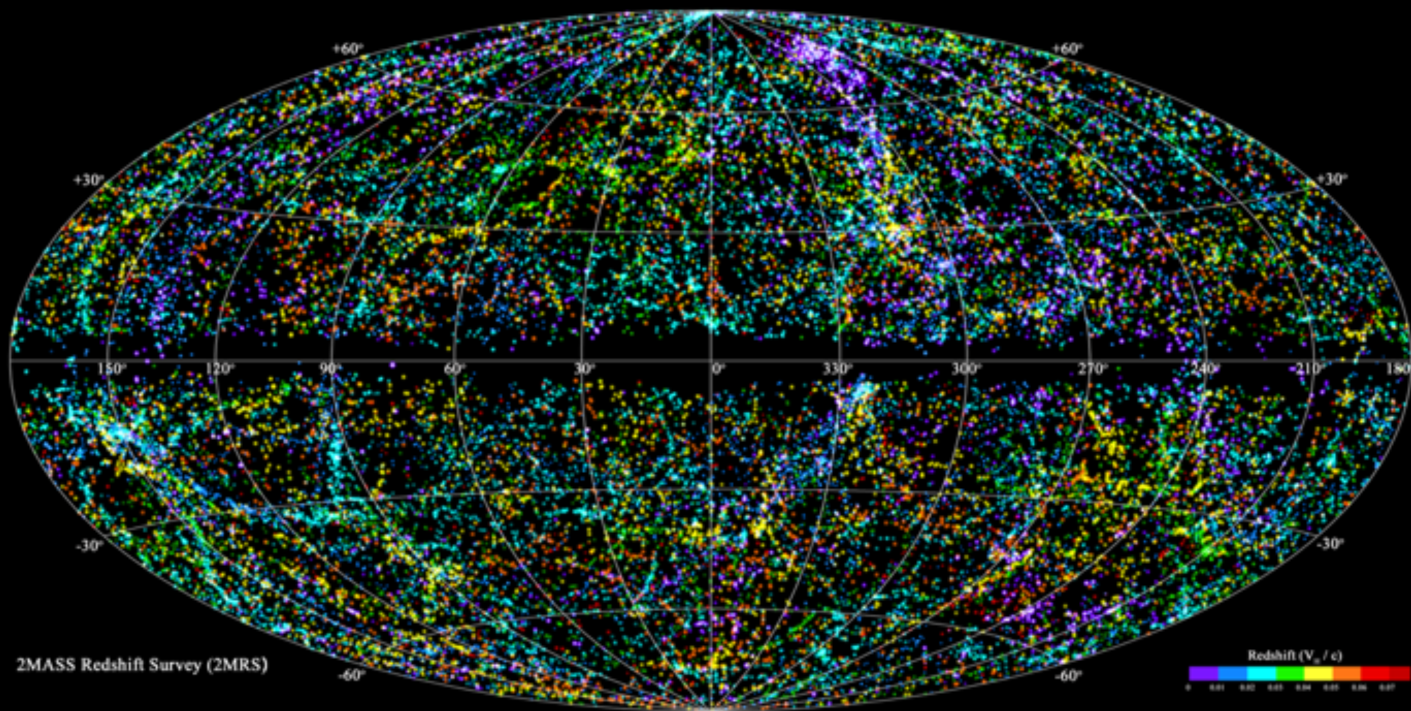
<u>Yanping Chen (NYUAD)</u>, Glennys Farrar (NYU)

Zaw, Chen, & Farrar, 2019, ApJ, 872, 134
Chen, Zaw, & Farrar, 2018, ApJ, 861, 67

AGN Catalog

- Construct an all-sky catalog based on optical spectra
  - Compare with all-sky catalogs at other wavelengths
  - Provide new (near-by) AGN to target in studies
- Ideally: Pure, Complete, Homogeneous
- Challenges
  - Dependence on subtraction of host galaxy contribution
  - Heterogeneous data: differences in spectral quality and resolution

Parent Sample: 2MRS

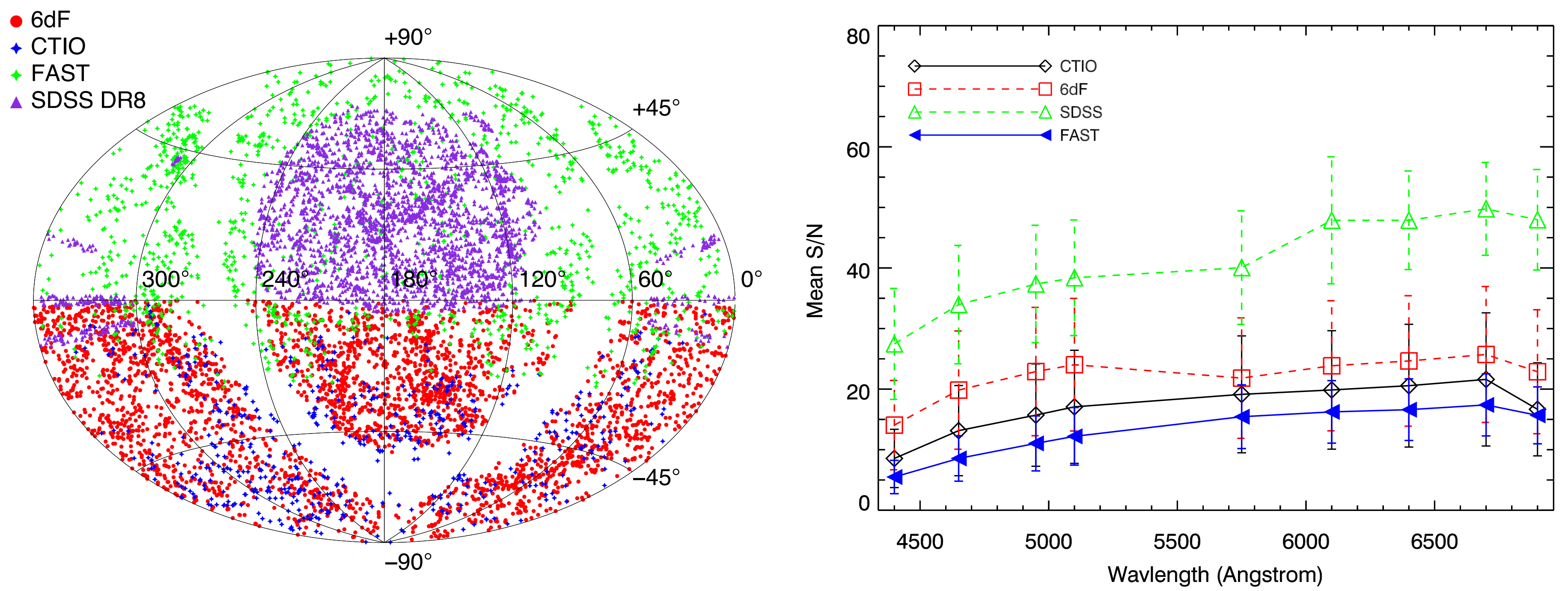


Huchra et al., 2012

- Near-complete census of the near-by (z <~ 0.09) universe outside the Galactic Plane

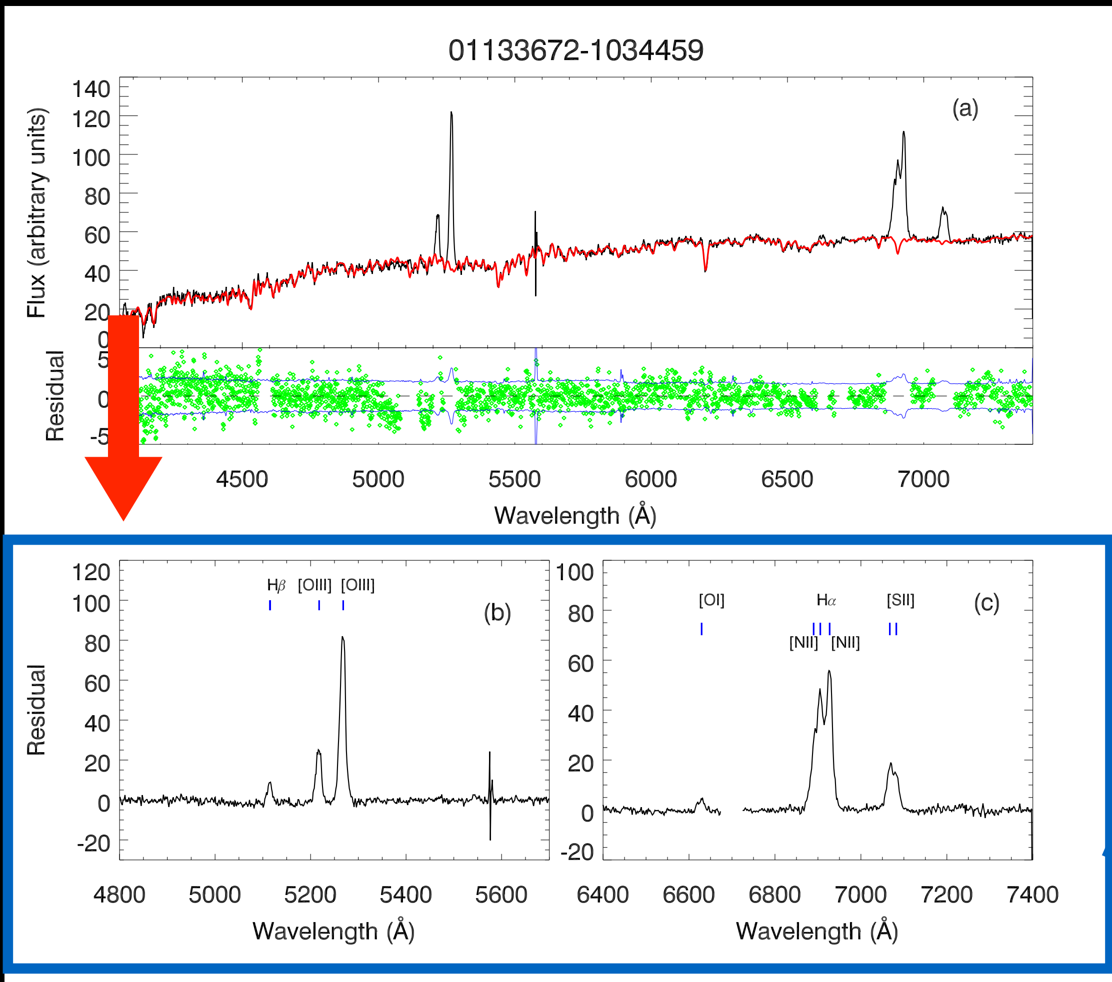
- Collected ~ 80% of the spectra, ~75% in 4 spectral subsamples

Spectral Subsamples



Zaw, Chen, & Farrar, 2019

Optical AGN Identification



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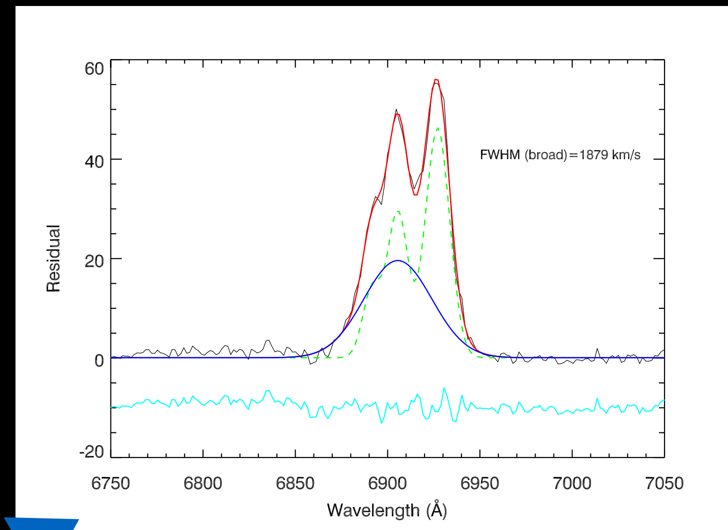
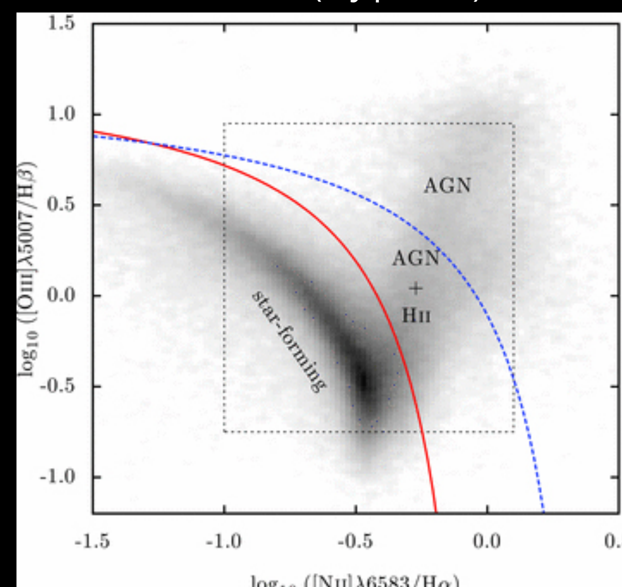
Broad-line (Type 1) AGN



Zaw, Chen, & Farrar, 2019

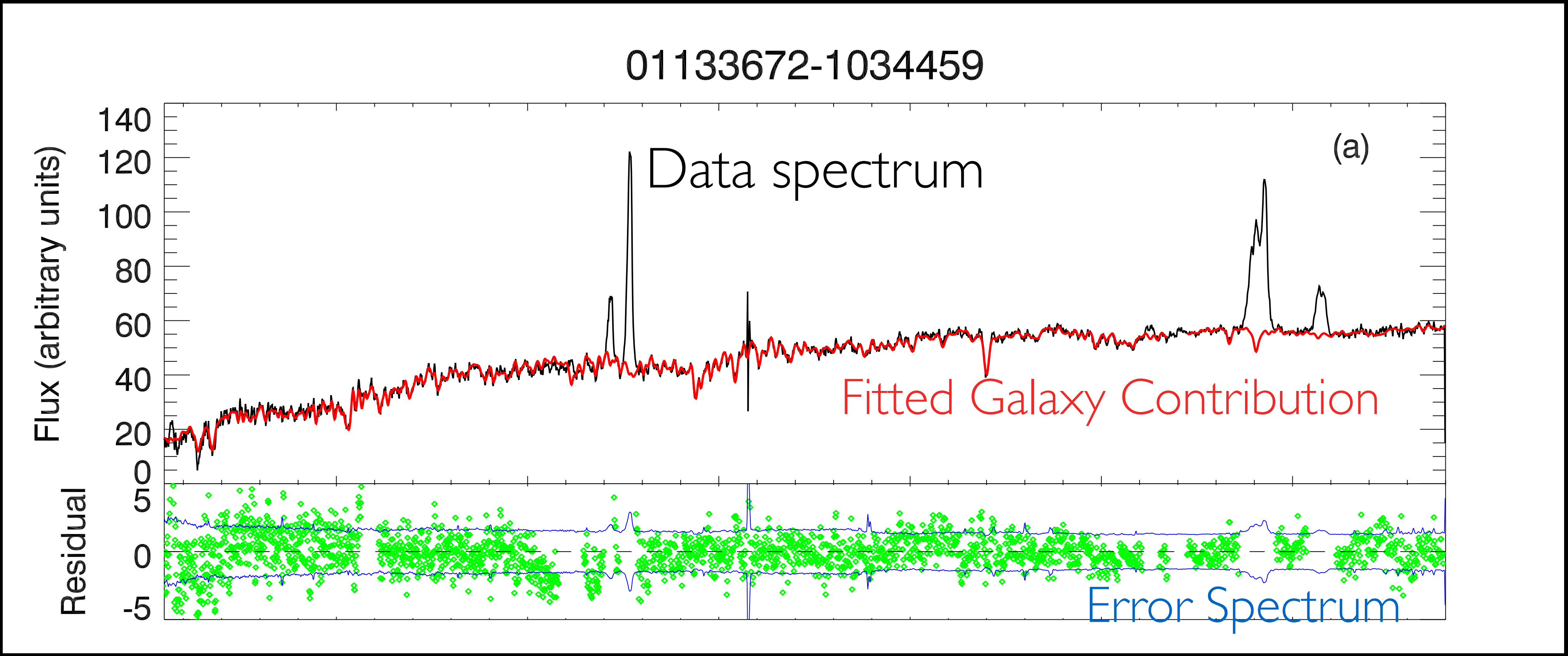
Narrow-line (Type 2) AGN



Dobos et al. (2012)

- Pros: Well defined and reliable
- Cons: Can miss obscured and low luminosity AGN, sensitivity to host galaxy subtraction

Host Galaxy Subtraction



Zaw, Chen, & Farrar, 2019

- Fitted Galaxy Contribution: Linear combination of single stellar population (SSP) templates
- Data/Error: Spectral signal-to-noise

Stellar Population Models

Emprical

- **MILES:** 3500-7500Å, 63Myr-18Gyr, Z=0.0001-0.03, purely empirical library
- MIUSCAT: 3500-9469Å, extended MILES models, purely empirical stellar libraries
- Maraston05: 0.3-2.5µm, 3Myr-15Gyr, Z=0.0001-0.04, mixed libraries
- Maraston11: 1000-25000Å, various metallicity depends on input stellar library, empirical libraries
- PEGASE-HR: 4000-6800Å, higher resolution of PEGASE, purely empirical library

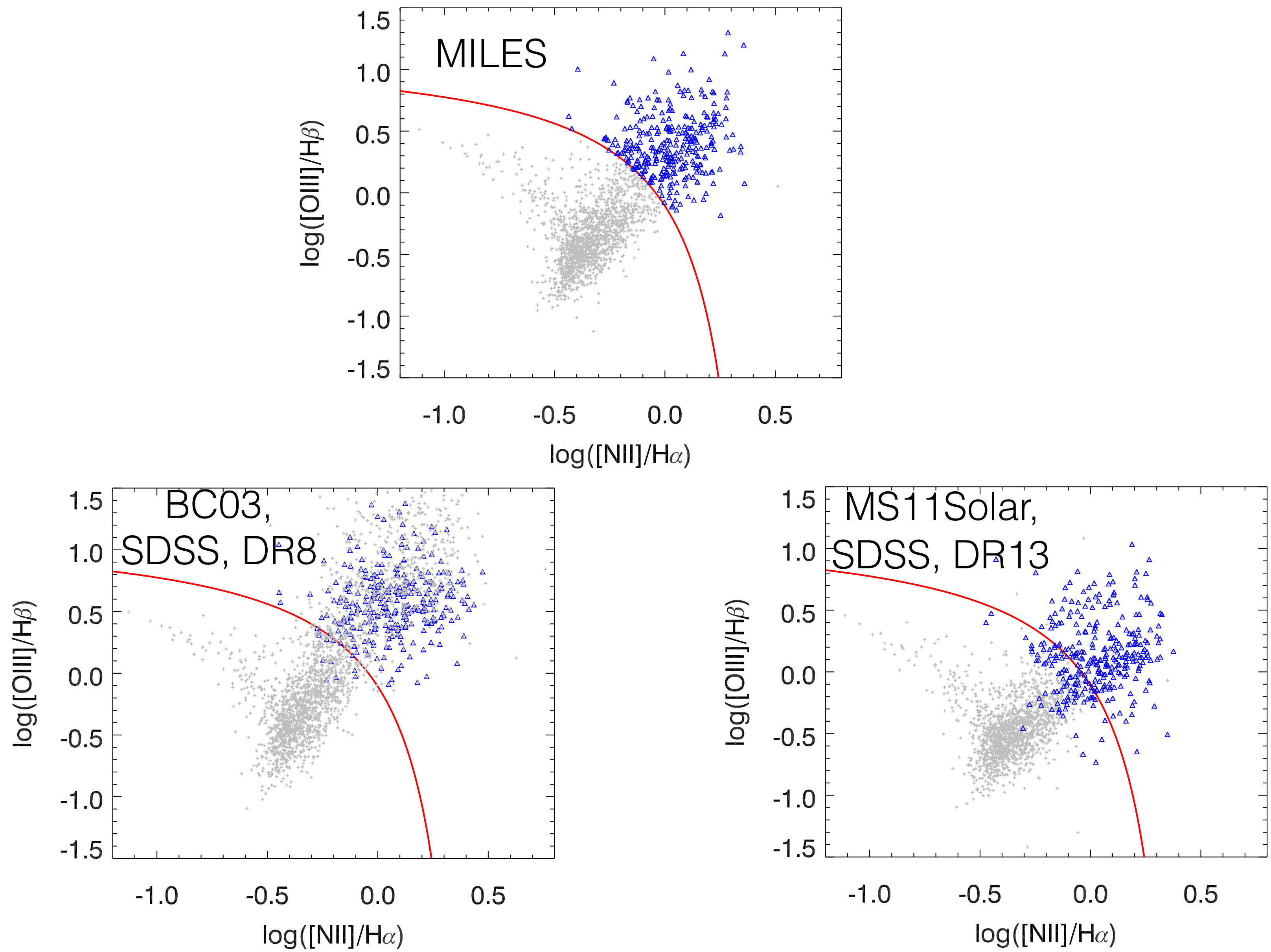
Mixed

- **BC03:** 91Å-160µm, 0.1Myr-20Gyr,Z=0.0001-0.05, mixed stellar library (empirical + theoretical)
- FSPS (Conroy09,10): 91Å-160µm, 3Myr-15Gyr, Z=0.0001-0.03, mixed stellar library (empirical + theoretical)

Theoretical

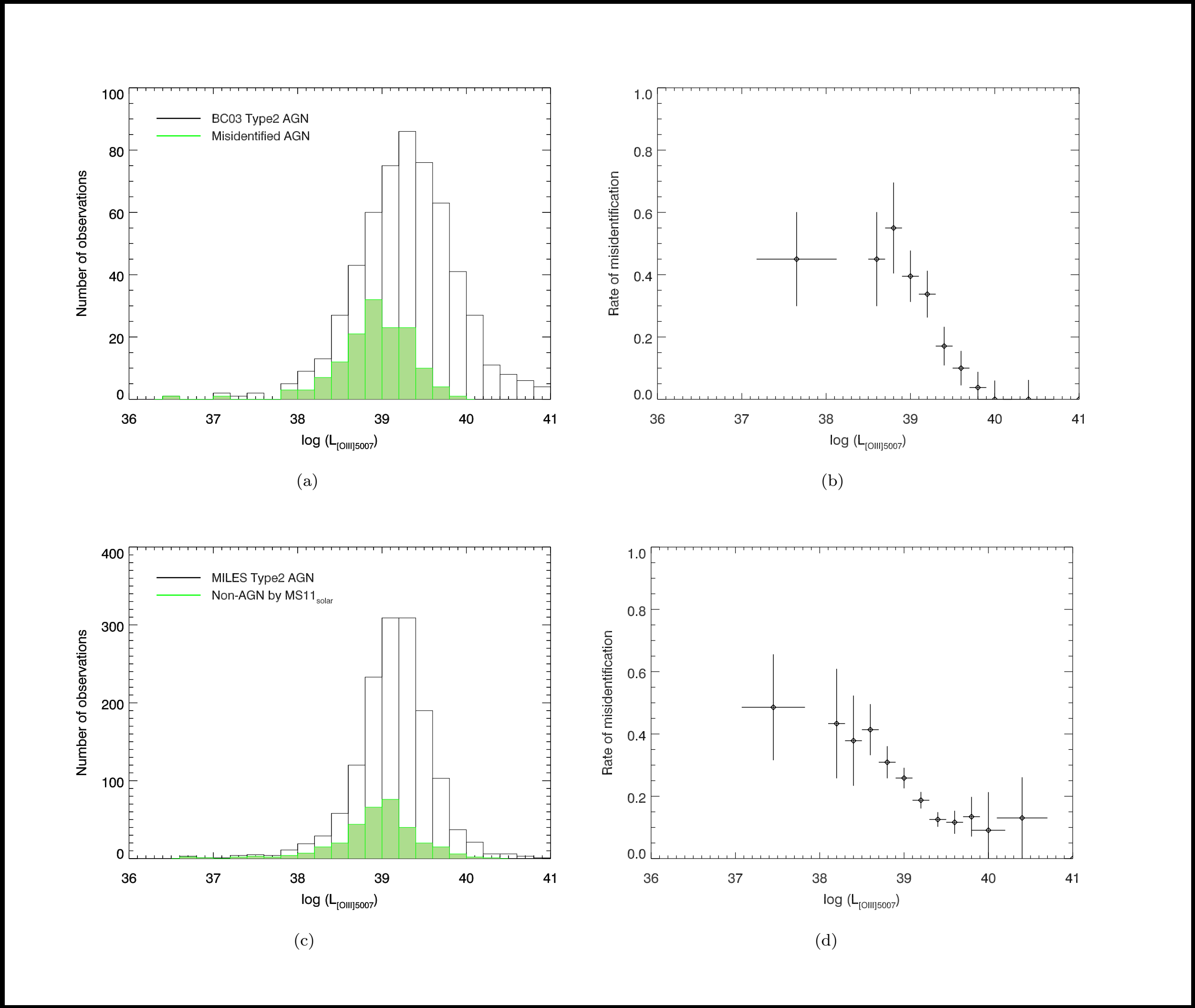
- Starburst99: 91Å-160µm, 1Myr-1Gyr, Z=0.001-0.04, purely theoretical stellar library
- PEGASE: 220Å-5µm, 1Myr-20Gyr, Z=0.0004-0.05, purely theoretical stellar library
- **González Delgado et al. 2005**: 3000-7000Å, 4Myr-17Gyr, Z=0.004-0.019, purely theoretical stellar library

Systematic Shift in Line Ratios



Zaw, Chen, & Farrar, 2019

Discrepancies Biggest at Low Luminosities



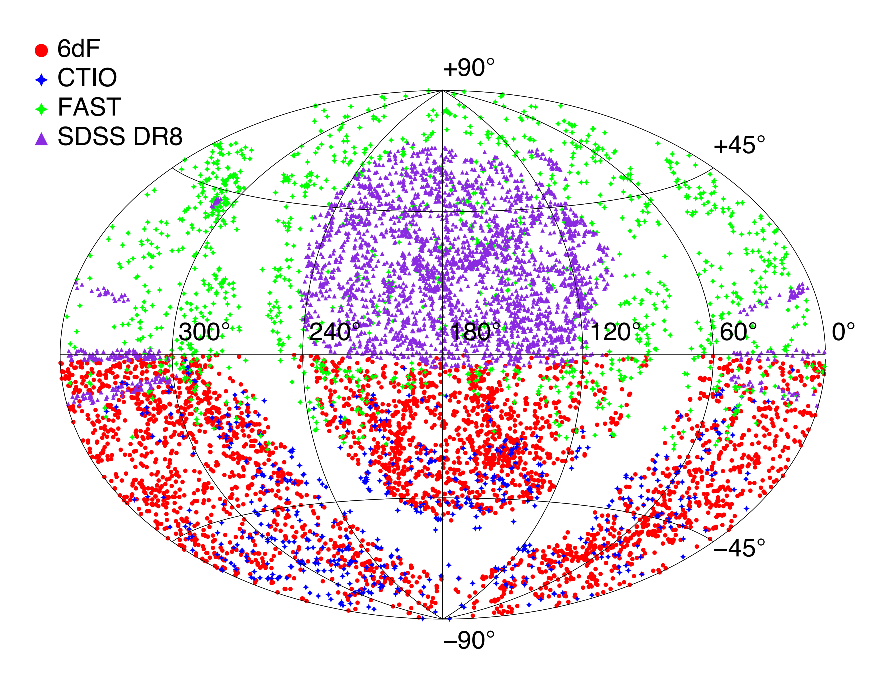
- MILES templates give the best results

Chen, Zaw, & Farrar, 2018

- Better stellar library than BC03, fits favor higher-than-solar metallicities

The Catalog

Identified AGNs



8491 AGNs

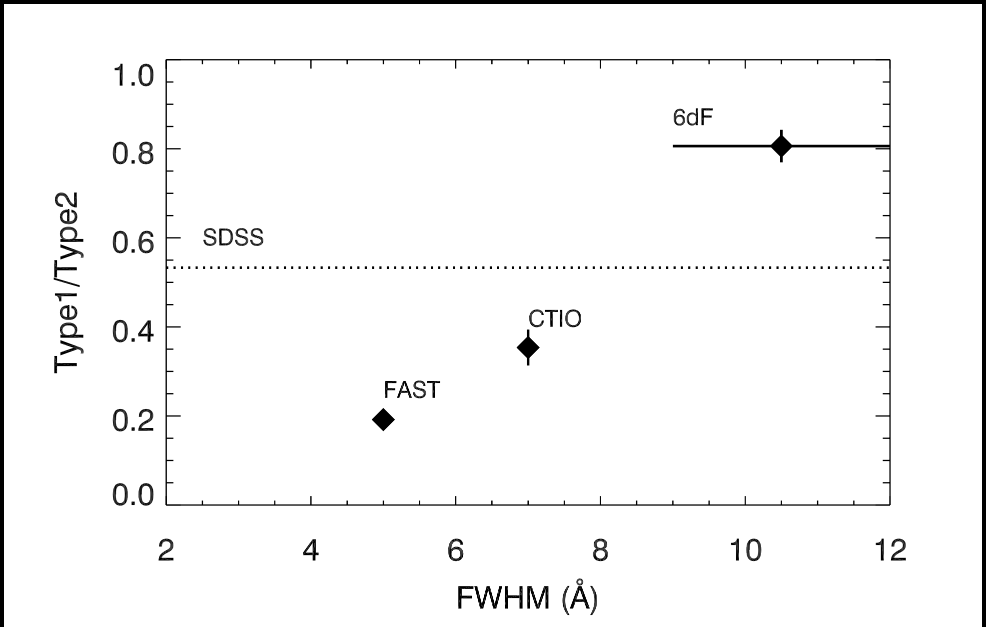
Table 2. AGN Numbers and Fractions

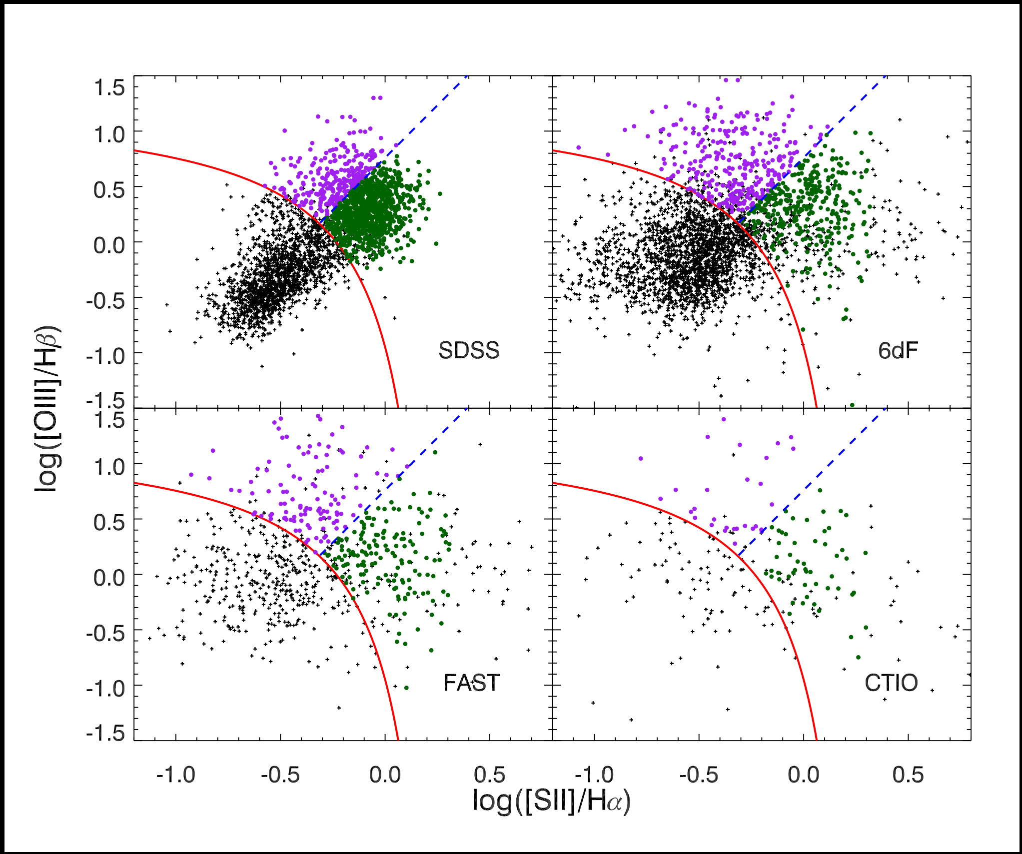
	Type 1	Type 2 K01	Type 2 K03
6dF	877 (8.47±0.30%)	1088 (10.51±0.33%)	2495 (24.09±0.54%)
SDSS	811 (11.47±0.43%)	1511 (21.38±0.61%)	2455 (34.73±0.81%)
FAST	137 (2.18±0.19%)	714 (11.39±0.45%)	1145 (18.26±0.59%)
CTIO	104 (3.65±0.36%)	294 (10.31±0.63%)	467 (16.38±0.82%)
Total	1929 (7.27±0.17%)	3607 (13.59±0.24%)	6562 (24.72±0.34%)

Zaw, Chen, & Farrar, 2019

- Broad-line: Halpha FWHM > 1000 km/s, Narrow-line: Kauffmann et al. 2003 criteria
- AGN properties: names, coordinates, type, subsample, S/N
- Additional: Fluxes, line widths, errors
- Users can customize section criteria

AGN Types

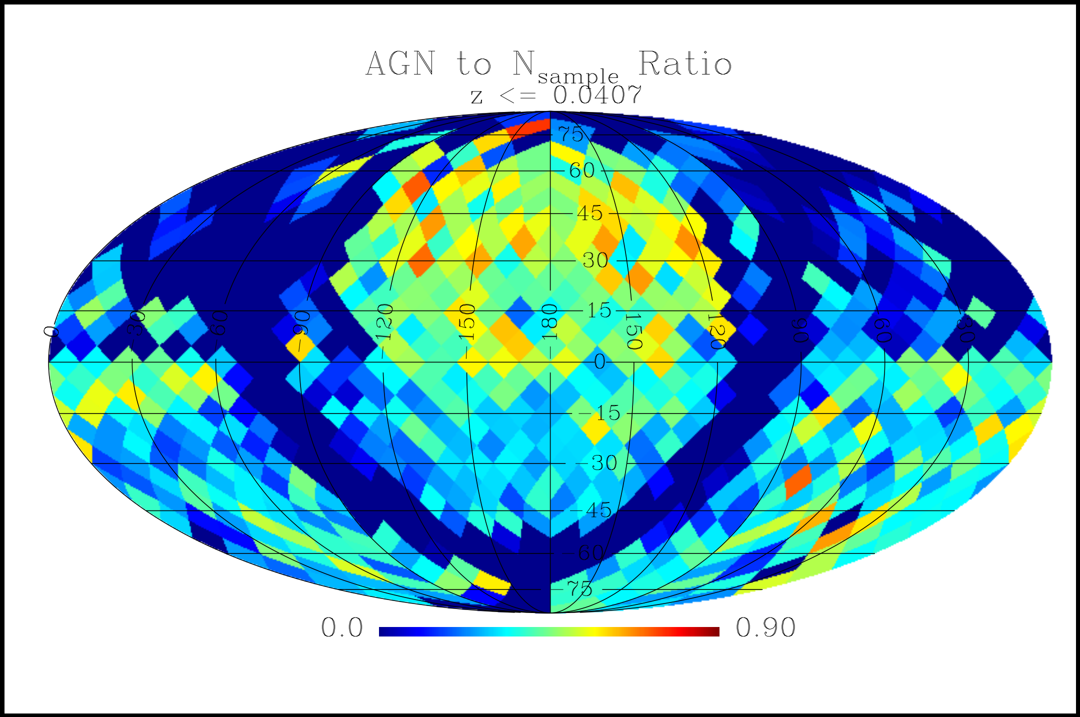


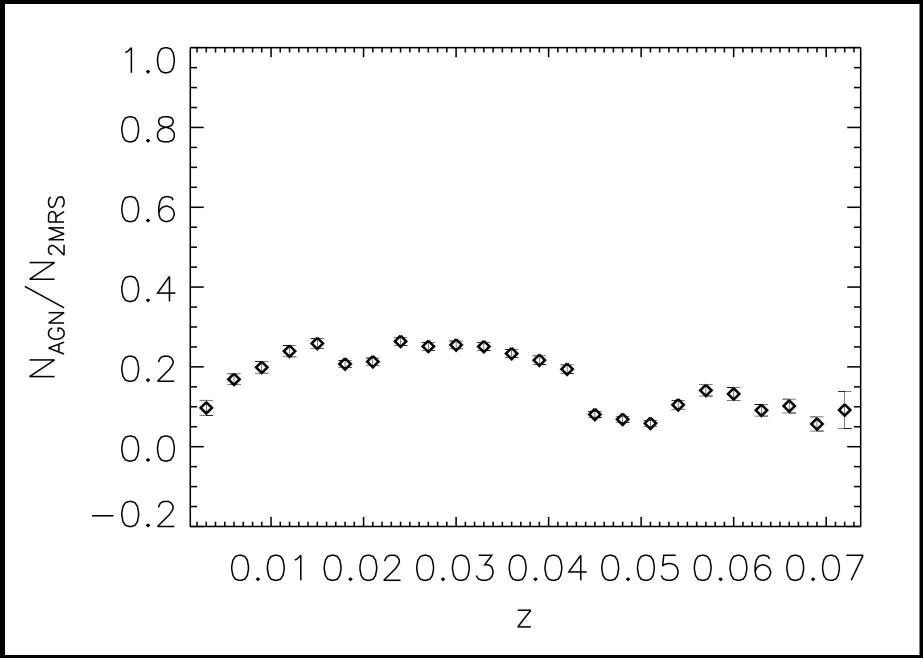


- Spectral S/N and resolution affect T1:T2 and Sy:LINER ratios
  - Higher T1:T2 for lower resolution
  - Higher S/N identifies more LINERs

Zaw, Chen, & Farrar, 2019

Inhomogeneities

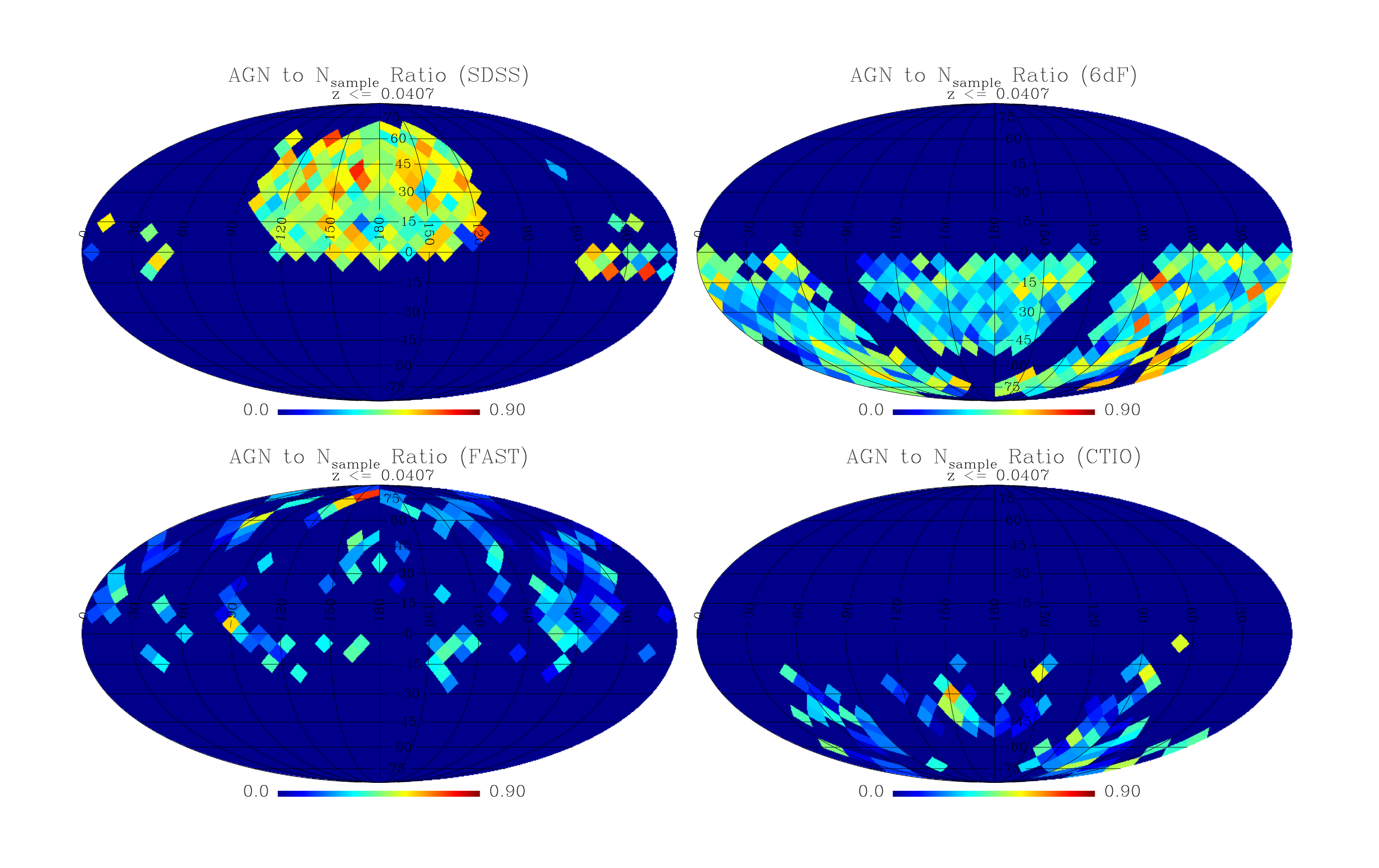




Detection rates vary across the sky and in z
(due to sky coverage of different subsamples)

Zaw, Chen, & Farrar, 2019

Inhomogeneities: Subsamples, Spatial



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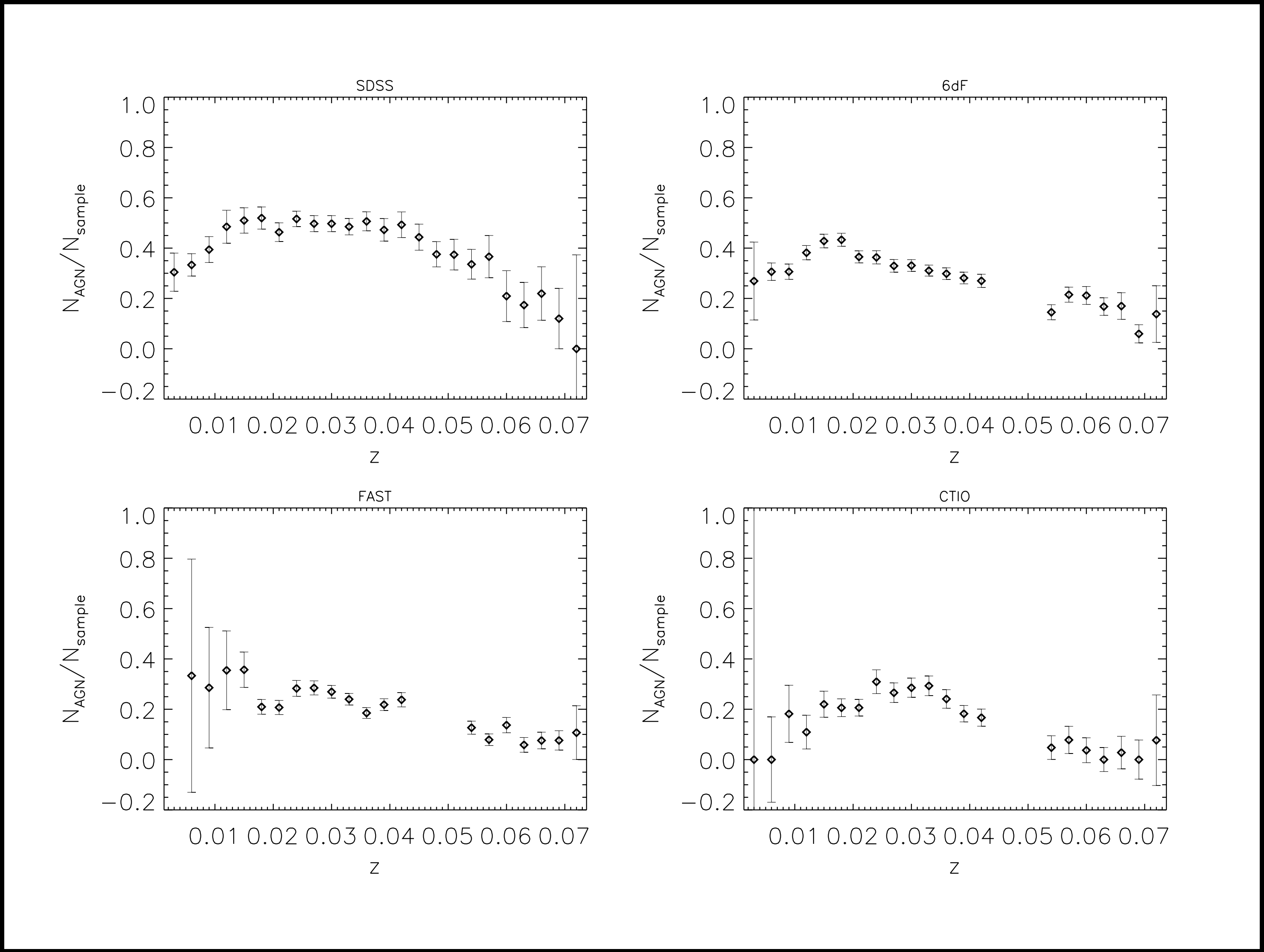
More homogeneous within a subsample

Inhomogeneities: Subsamples, Redshift



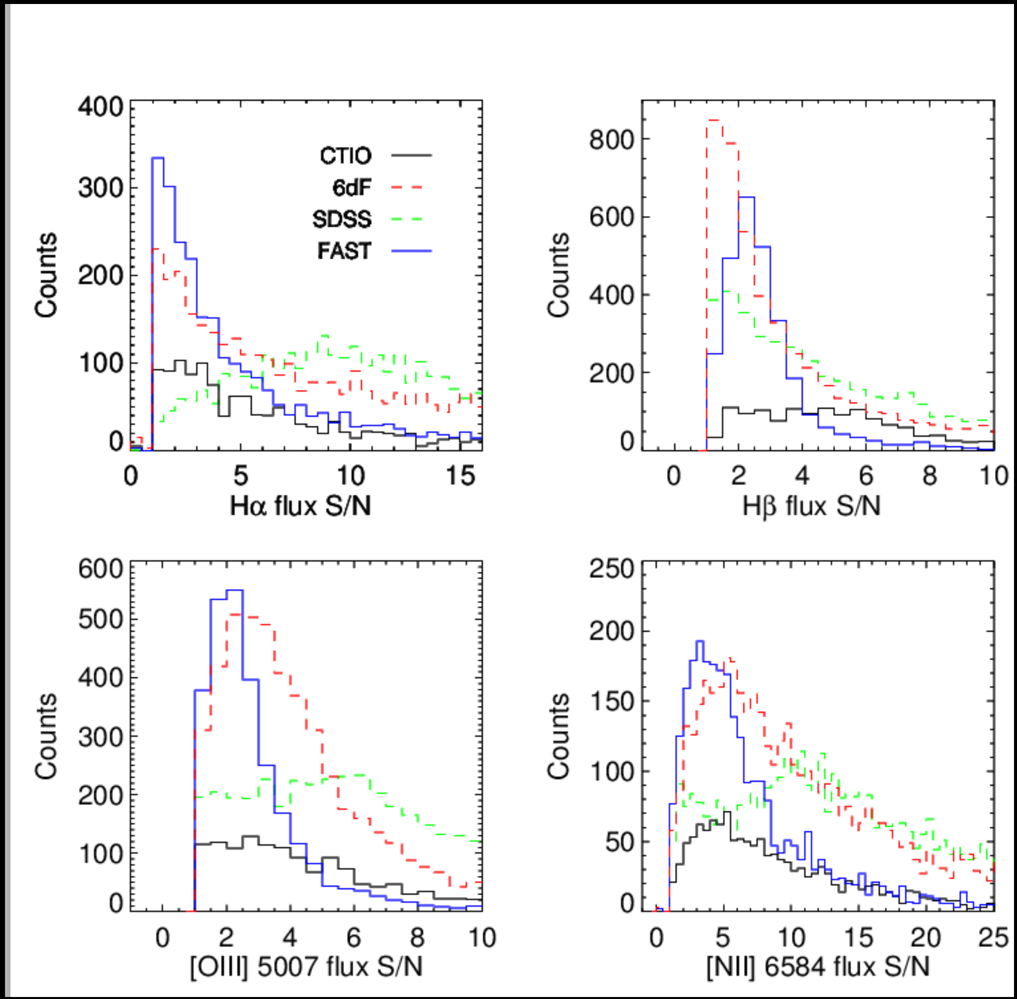
More homogeneous within a subsample

Zaw, Chen, & Farrar, 2019

Data Quality Effects and Statistical Corrections

Effects of Spectral S/N

S/N of Lines



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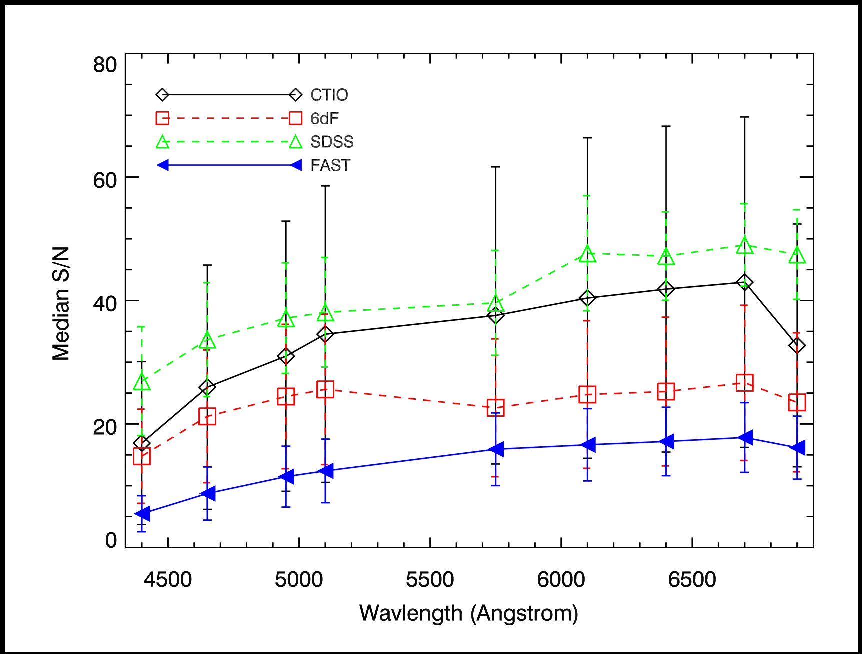
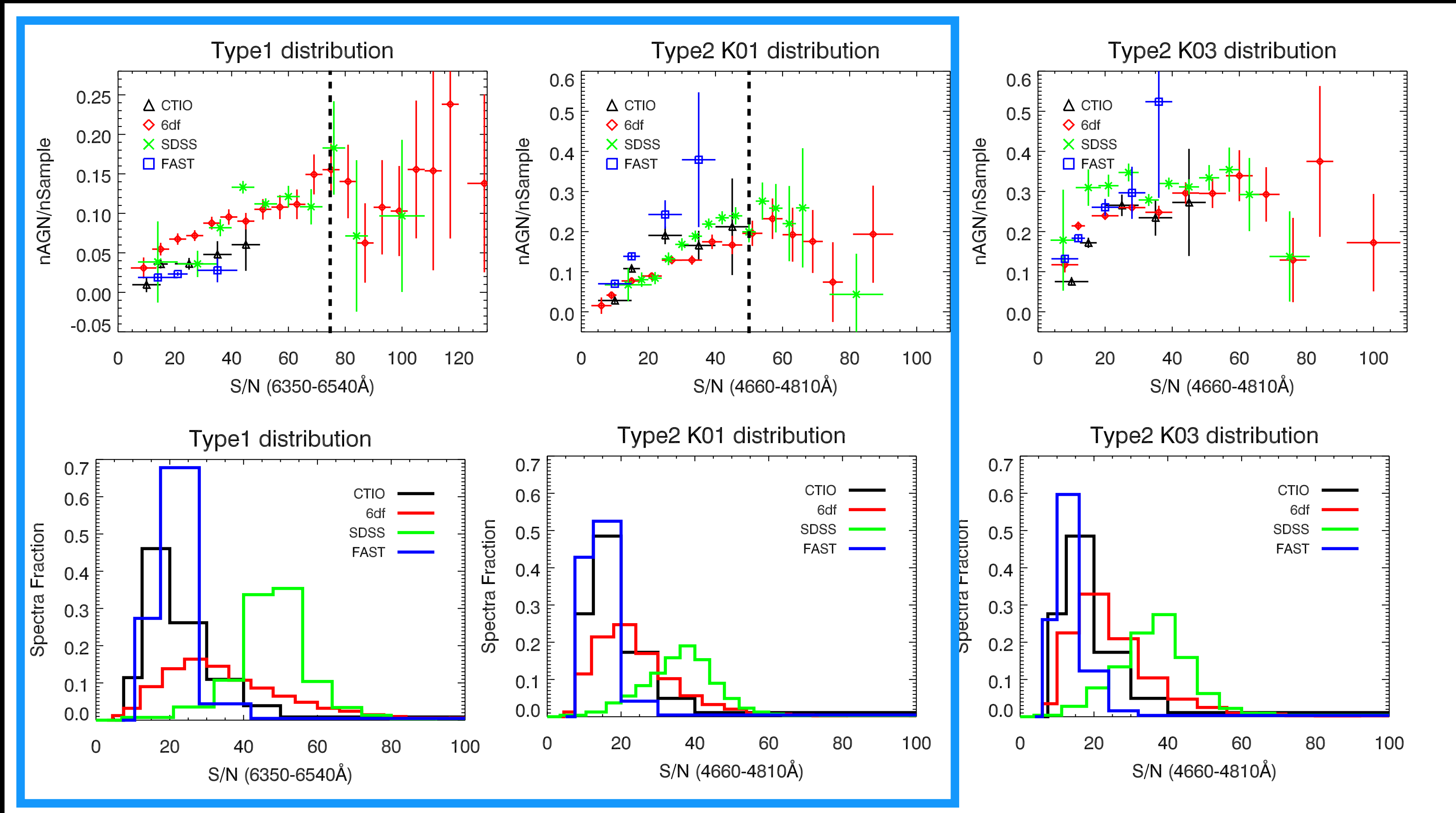
S/N in Continuum Regions



Better measure of spectral quality

AGN Identification Rate Determined by Continuum S/N



Rate vs S/N

$$
\begin{aligned}
R_{fT1} =&(SN1) * 0.002412 - 0.01400 \text{ for } SN1 < 76 \\
=&0.1693 \equiv R_{sT1} \qquad\qquad \text{ for } SN1 \geq 76 \\
R_{fT1} =&(SN2) * 0.004621 - 0.01214 \text{ for } SN2 < 50 \\
=&0.2432 \equiv R_{sT2} \qquad\qquad \text{ for } SN2 \geq 50
\end{aligned}
$$

AGN Likelihood

$$
L_{T1} = \frac{R_{sT1} - R_{fT1}}{1 - R_{fT1} - R_{fT2}}
$$

$$
L_{T2} = \frac{R_{sT2} - R_{fT2}}{1 - R_{fT1} - R_{fT2}},
$$

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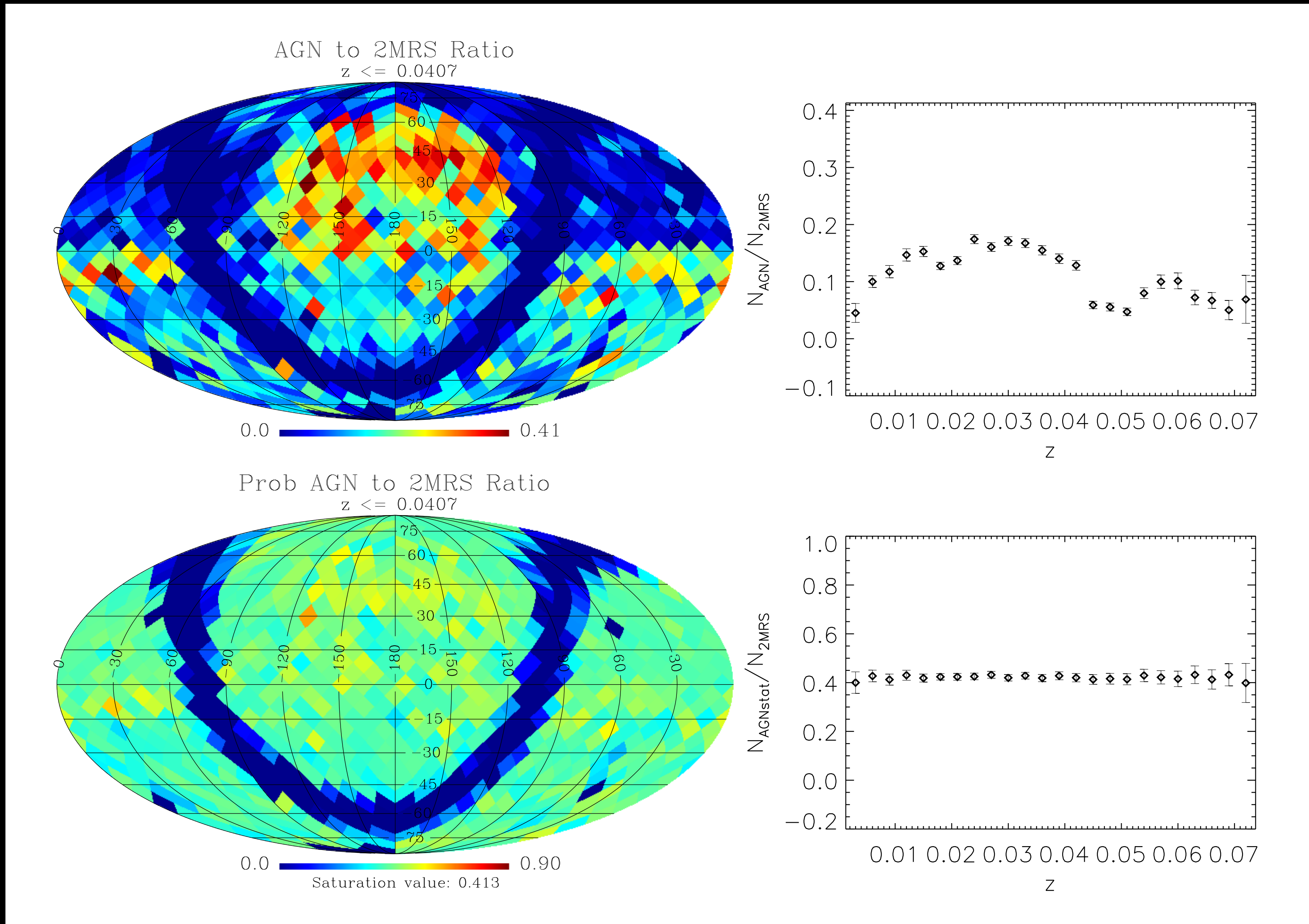
Statistically Corrected Catalog

Uncorrected

Corrected

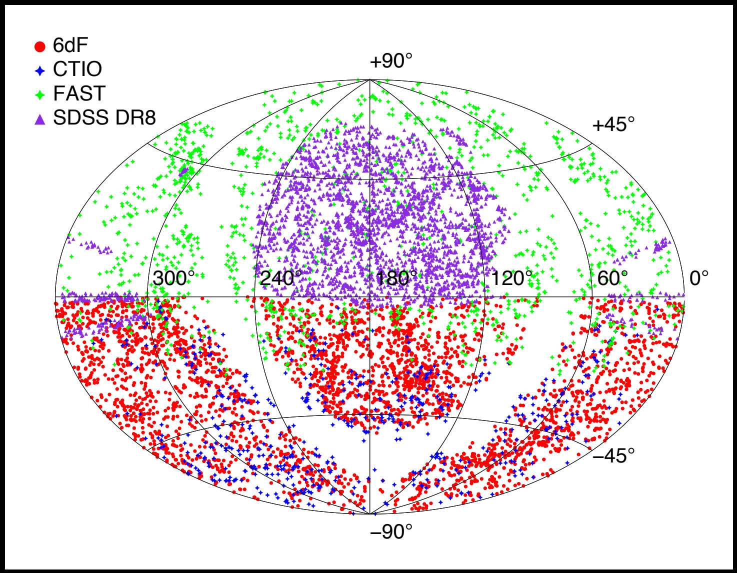


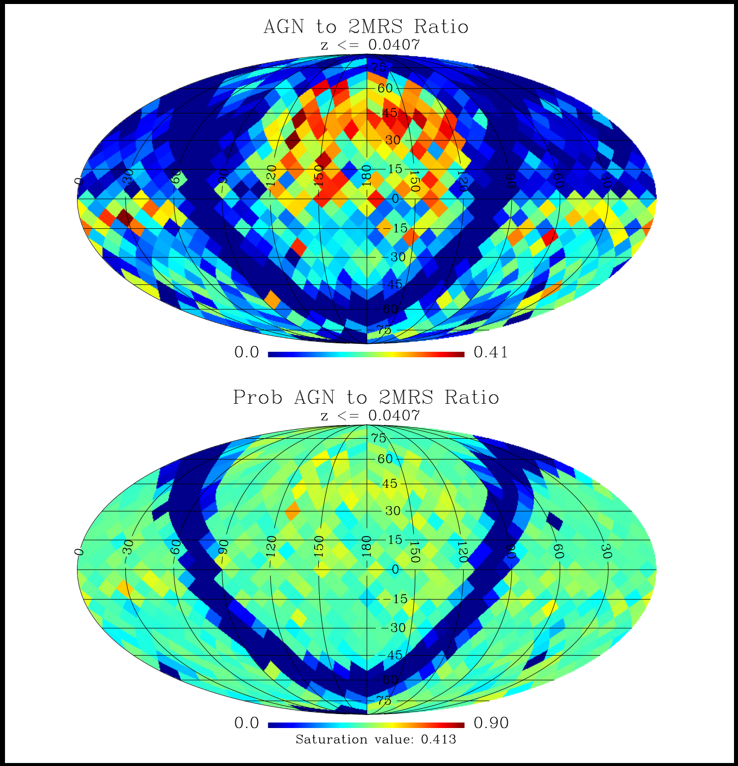
Also accounts for galaxies without spectra

Zaw, Chen, & Farrar, 2019

Conclusions

- A pure, complete, homogeneous, all-sky AGN catalog is necessary for studies of astrophysical particle acceleration
- Constructed an AGN catalog from a uniform, complete parent galaxy sample
- Statistically correct for incompletenesses and inhomogeneities resulting from differences in data quality
- Started cross-correlation studies with BAT105, WISE, and Radio (all sky) AGN catalogs

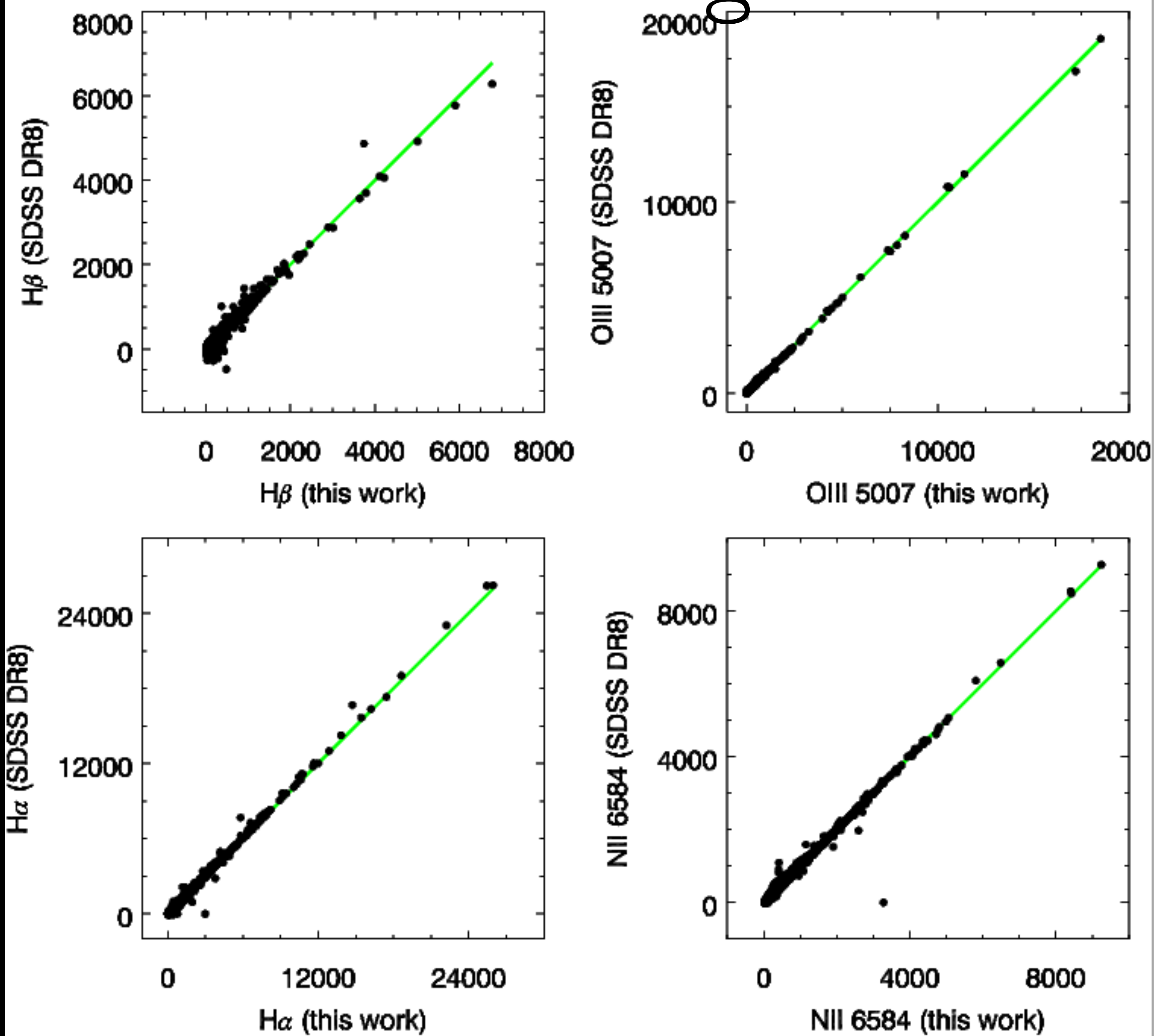




Backup Slides

SDSS Data: DR8 with BC03 templates, Ours with MILES templates

Fluxes Agree



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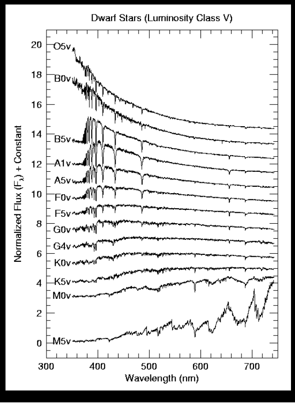
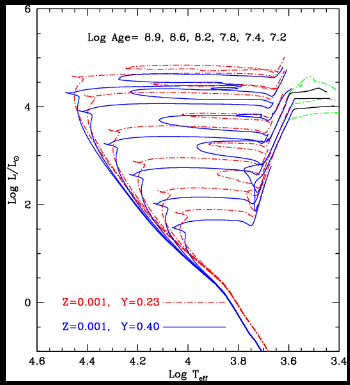
Single Stellar Population (SSP) Models

Inputs

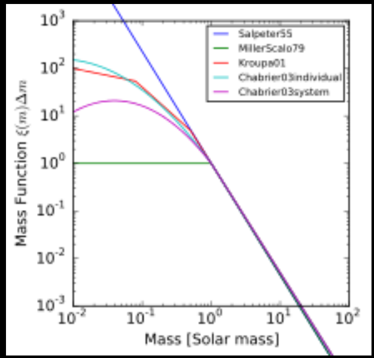
Stellar Library
Spectra of stars
Data and/or Theory



Isochrone
Evolutionary model
Age and metallicity

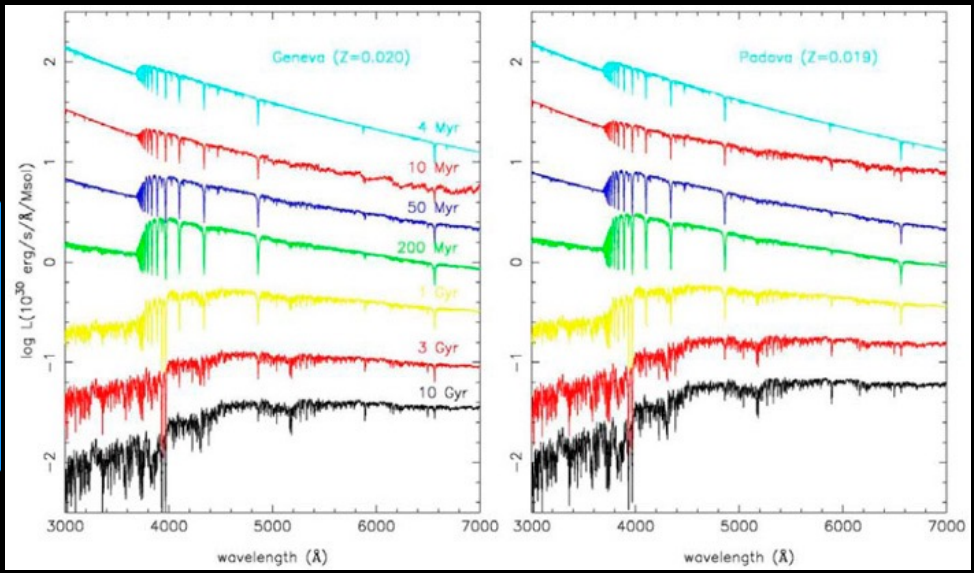


Initial Mass Function
Empirical function



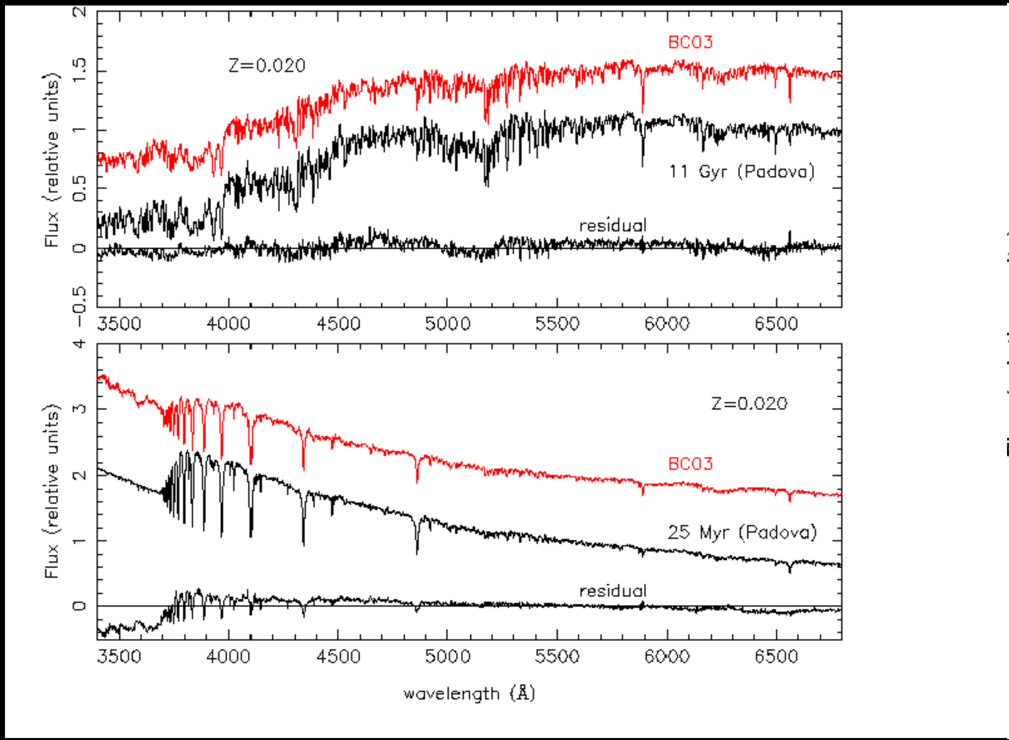
Output

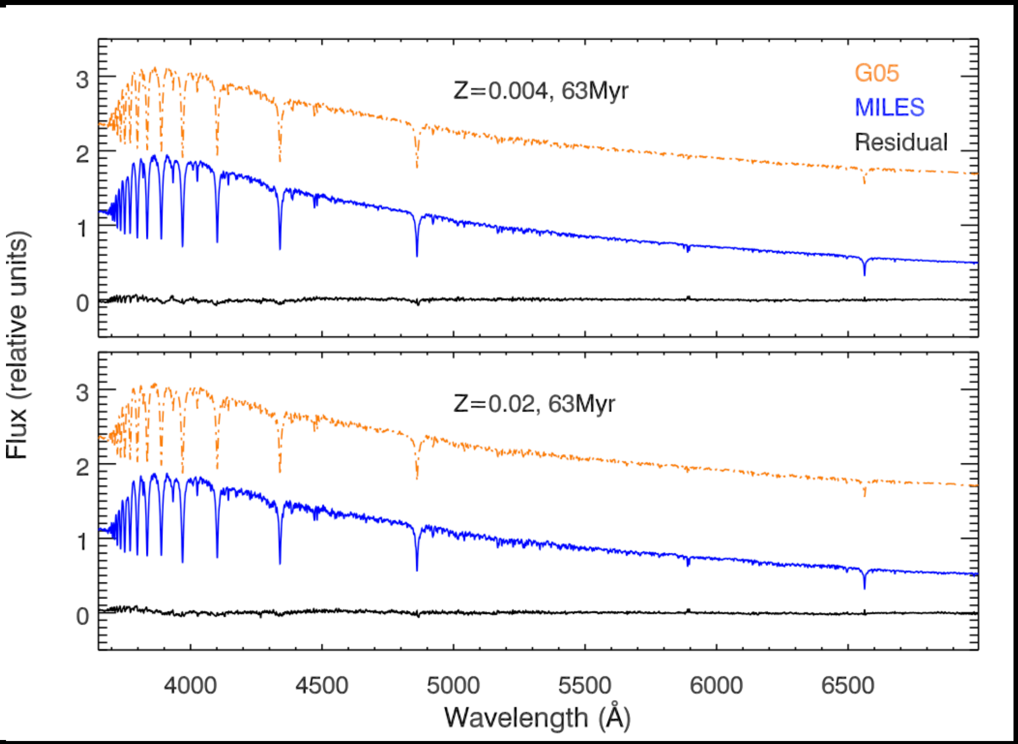
Single Stellar Population Models
Spectra of stellar populations
Empirical, theoretical, or mixed
Age, Metallicity, Wavelength range



Gonzalez-Delgado et al. (2005)

Origin of Discrepancies

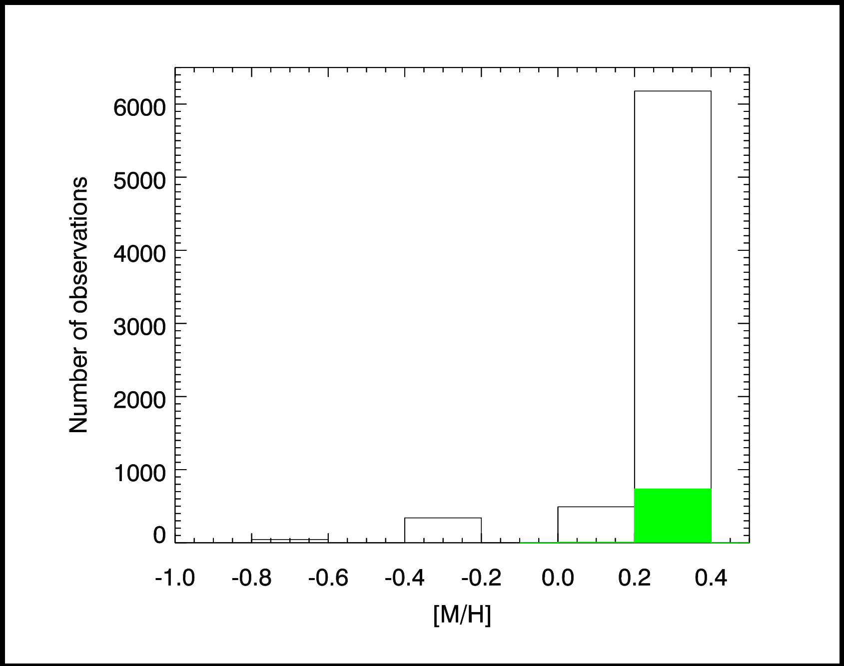




Chen, Zaw, & Farrar, 2018

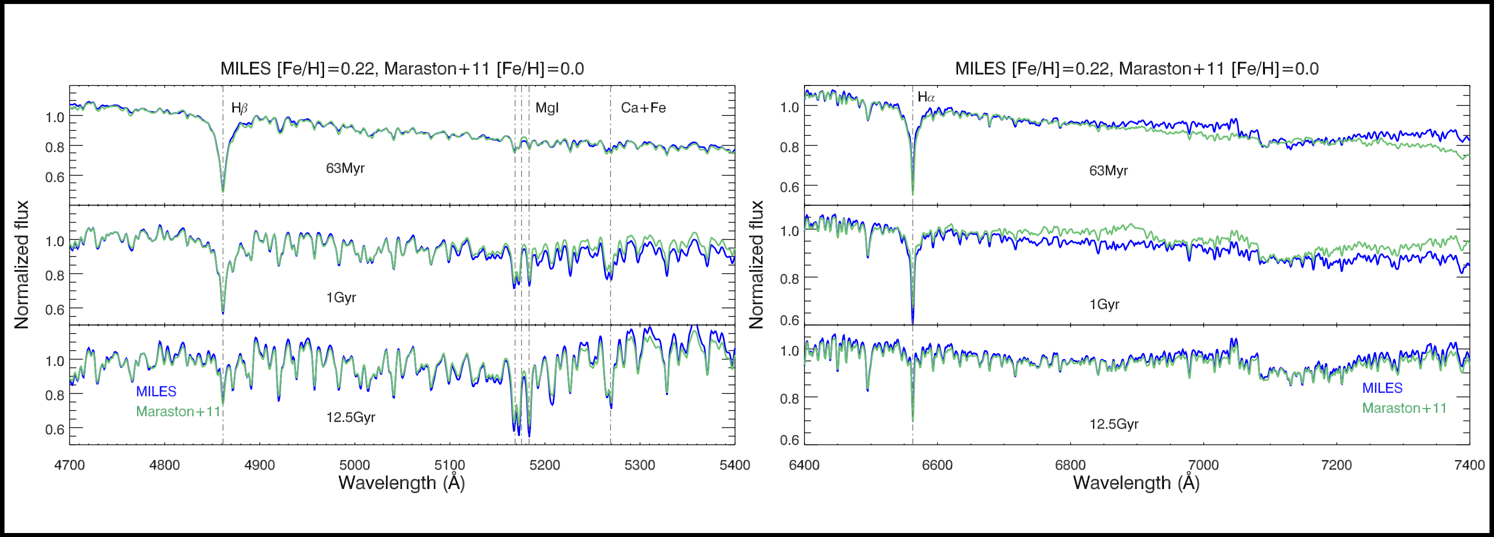
- Comparison with theoretical SSPs
- BC03 based on a smaller, less well calibrated stellar library. Corrected colors but not lines for younger populations.

Origins of Discrepancies



Thomas et al. 2013 use only solar metallicity templates from Maraston & Strombeck 2011

Our fits favor higher metallicity templates



Chen, Zaw, & Farrar, 2018