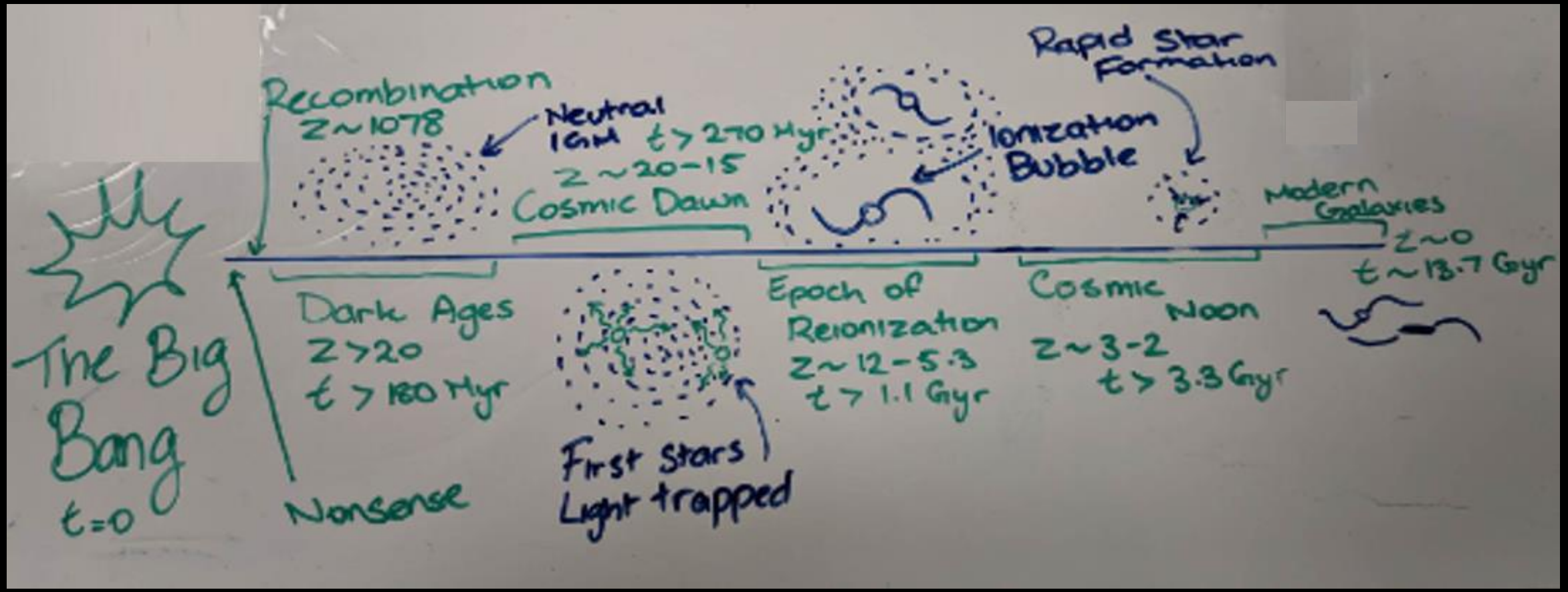
Determining the model dependence of the ionizing photon production efficiency through EoR analog galaxies at cosmic noon

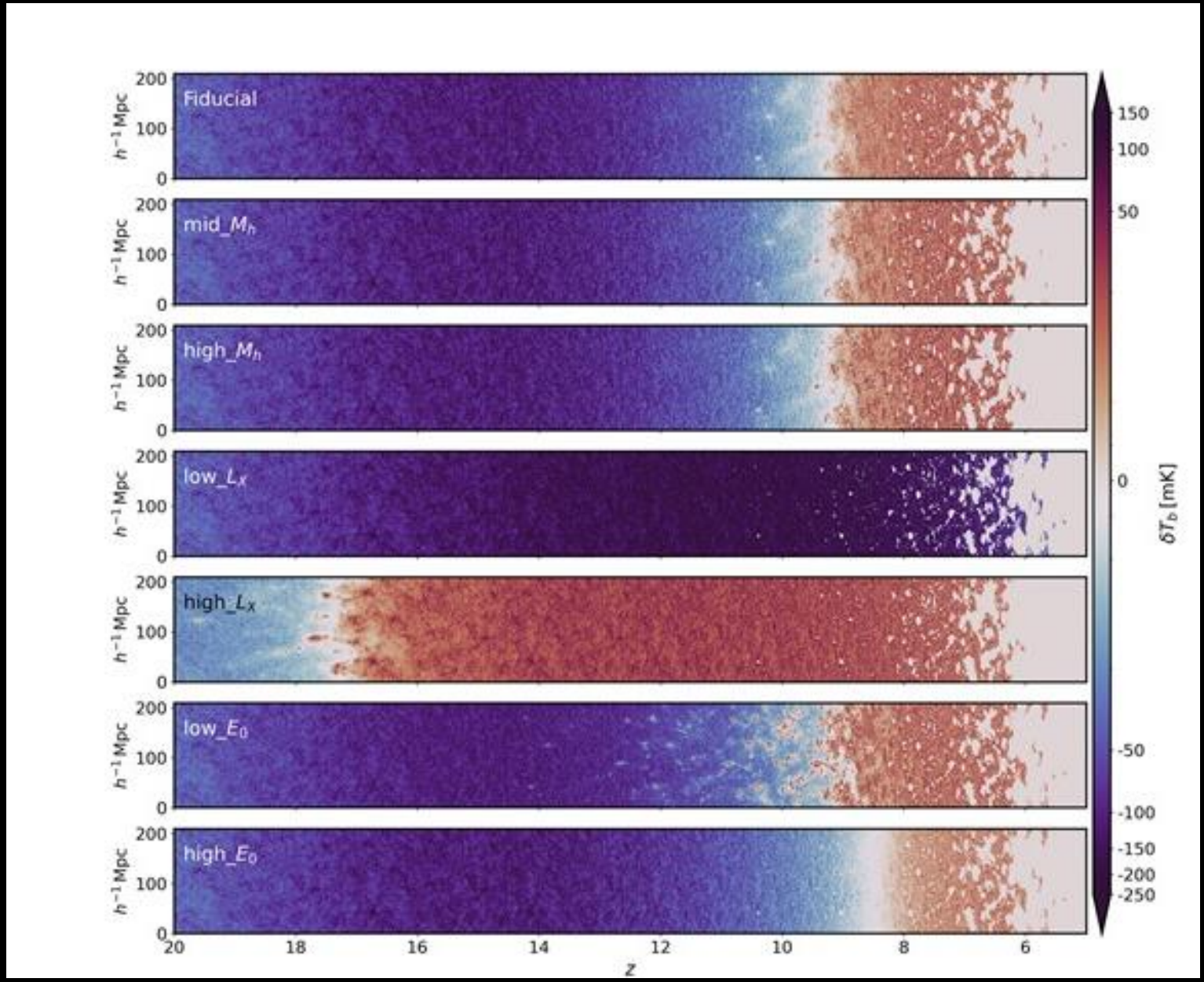
RAVI JAISWAR

Condensed History of the Universe



Reionization Simulations

- Cook et al 2023



An observational perspective

$$\frac{dQ_{HII}}{dt} = \frac{\dot{n}_{ion}}{\bar{n}_H} - \frac{Q_{HII}}{\bar{t}_{rec}}$$

ionization rate recombination rate

$$\dot{n}_{ion} = f_{esc} \times \xi_{ion} \times \rho_{UV}$$

$$\xi_{ion} = \frac{Q_{H^0}}{L_{UV}} [s^{-1}/ergs^{-1}Hz^{-1}]$$

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ionization rate recombination rate

How long reionization takes

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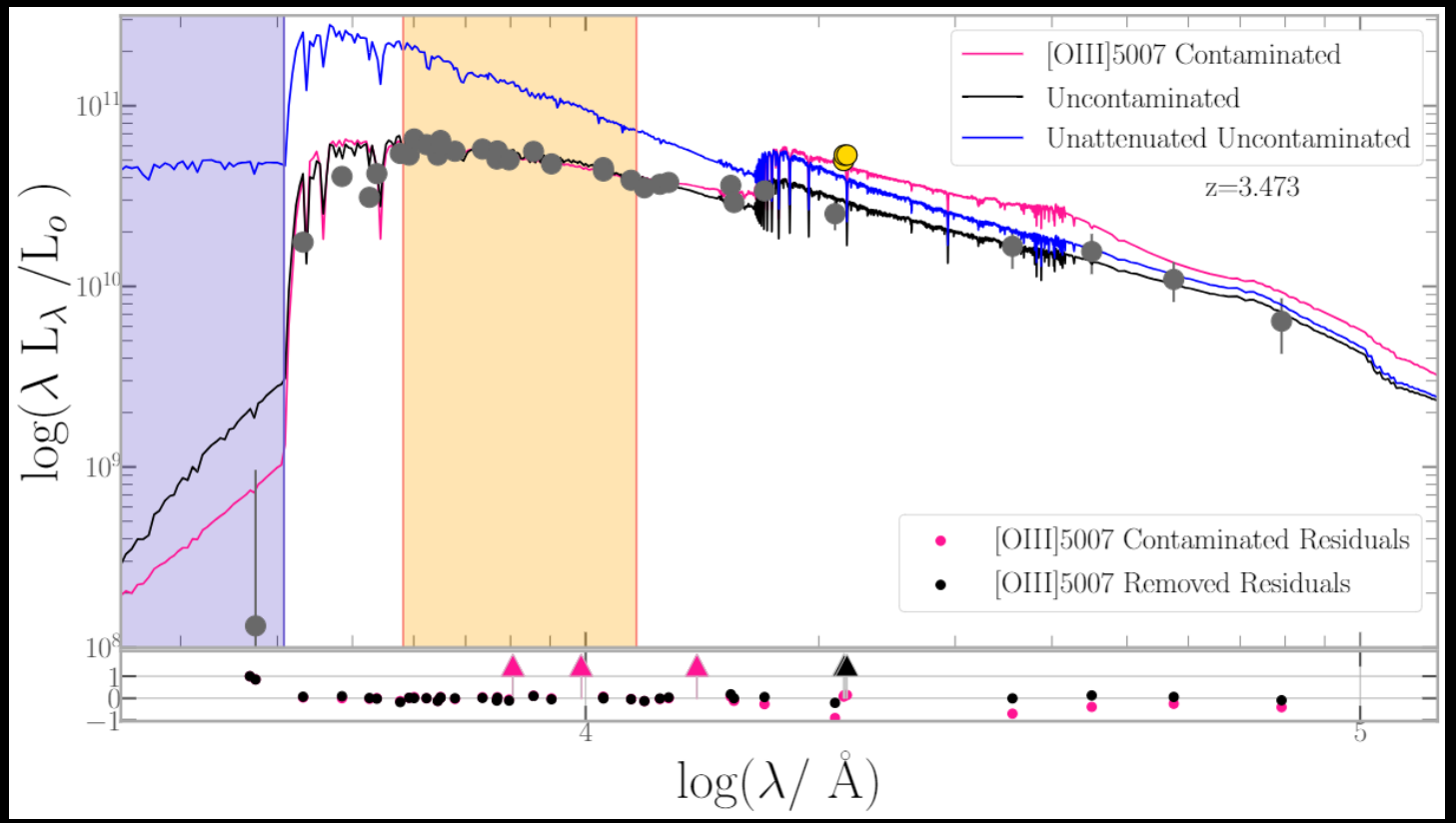
Fraction of escaping LyC over total produced LyC

Fraction of UV produced in the LyC (<912A) vs that produced in non-ionizing UV

$$\xi_{ion} = \frac{Q_{H^0}}{L_{UV}} [s^{-1}/ergs^{-1}Hz^{-1}]$$

Ionizing photon production efficiency



- Using the Ha flux as an indicator of LyC, converting to a rate, and normalizing by 1500A flux (redshift evolution)

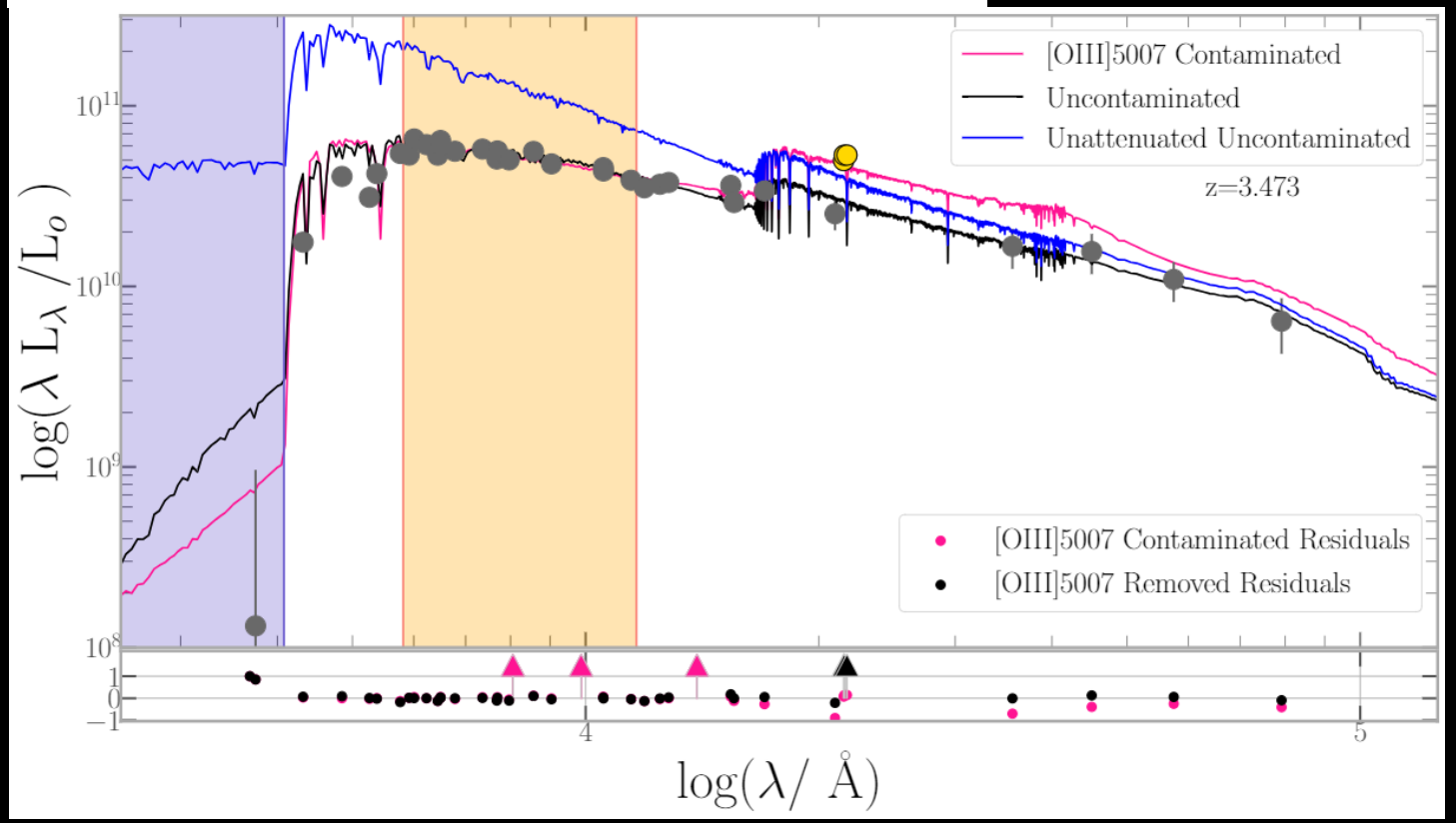
$$\xi_{ion} = \frac{N(H_\alpha)}{L_{UV}} = \frac{N(H_\beta)}{L_{UV} \times c_{rec}}$$

Spectroscopic method

Ionizing photon production efficiency

$$(\xi_{ion}/(\mathrm{Hz\ erg^{-1}})) = \int_{\infty}^{c/912} L_\nu(\mathrm{h}\nu)^{-1}/L_\nu(1500)\mathrm{d}\nu$$

Integration method



- Using the Ha flux as an indicator of LyC, converting to a rate, and normalizing by 1500A flux (redshift evolution)
- Integrating the LyC from an attenuation-corrected SED and normalizing by the 1500A flux

$$\xi_{ion} = \frac{N(H_\alpha)}{L_{UV}} = \frac{N(H_\beta)}{L_{UV} \times c_{rec}}$$

Spectroscopic method

The Sample

To study this, I've focused on 76 galaxies in the cosmic noon period ($2.5<z<4$).

These galaxies (EELGs) have [OIII]5007 EW similar to EoR galaxies

Of these 76, 53 overlap with the JADES and FRESCO surveys (JESCO) which replaces my ground based ZFOURGE survey data

Why Analogs?

They have an accessible LyC (high energy) emission

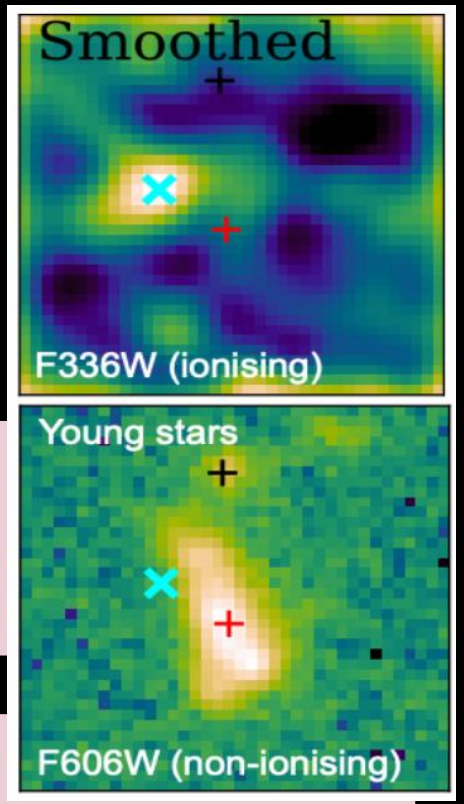
They have a similar morphology- similar mode of LyC escape

You can properly inform the SED

Why Analogs?

Gupta + Jaiswar 2024

Ji et al 2023, Kerutt et al 2024



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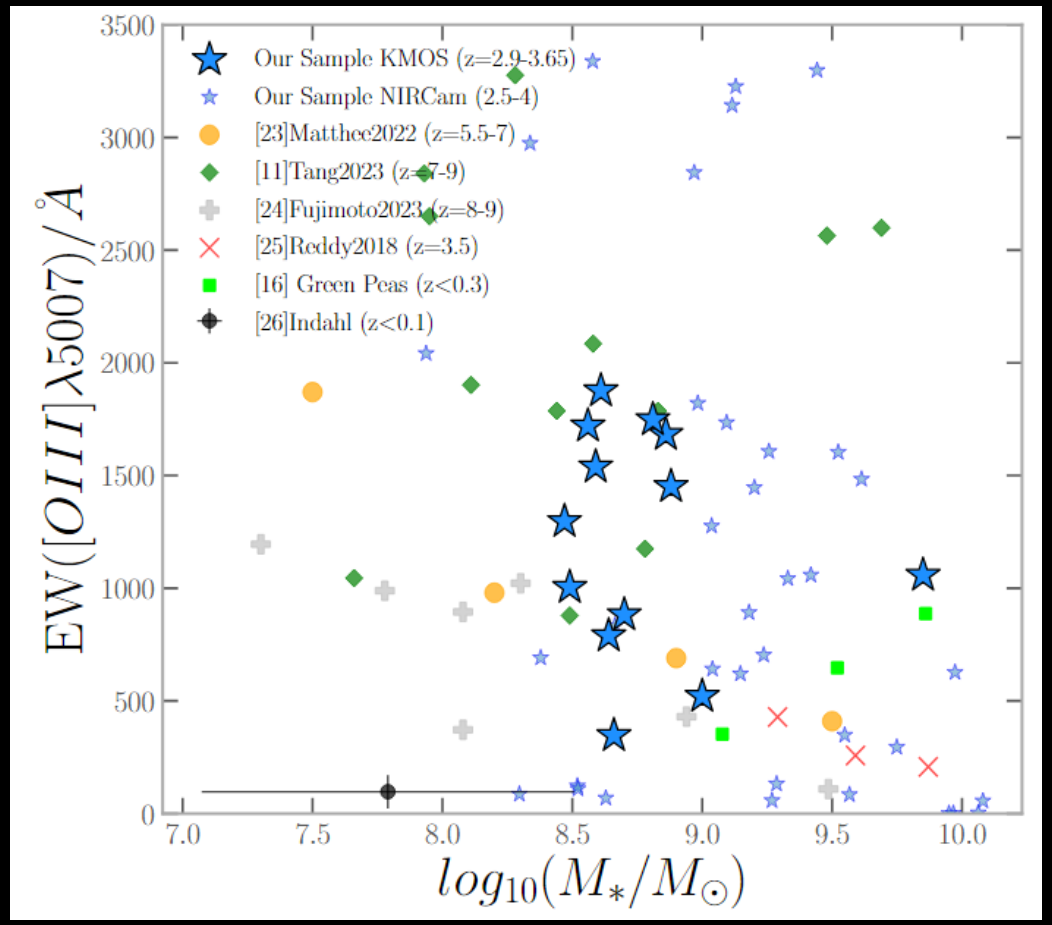
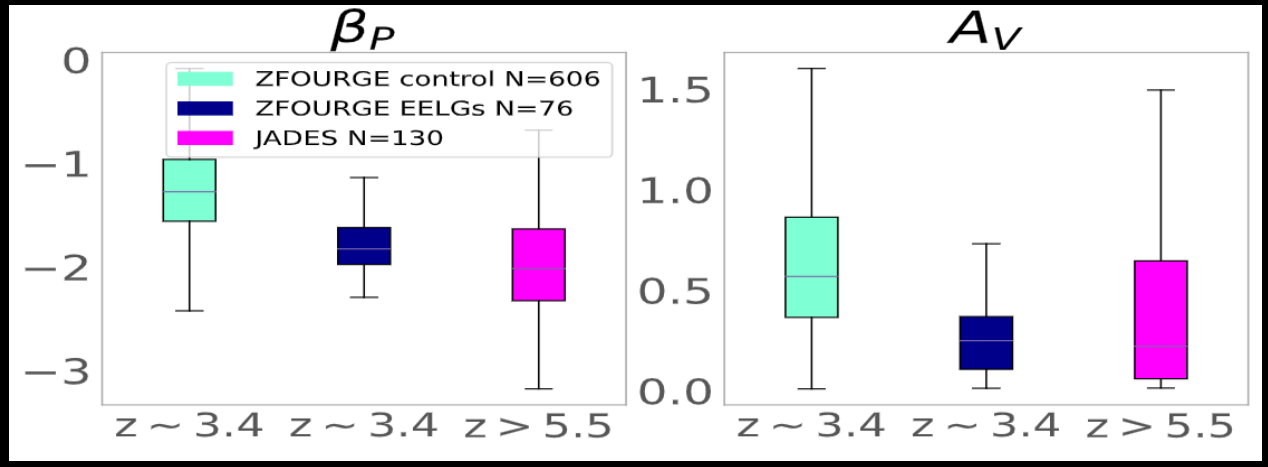
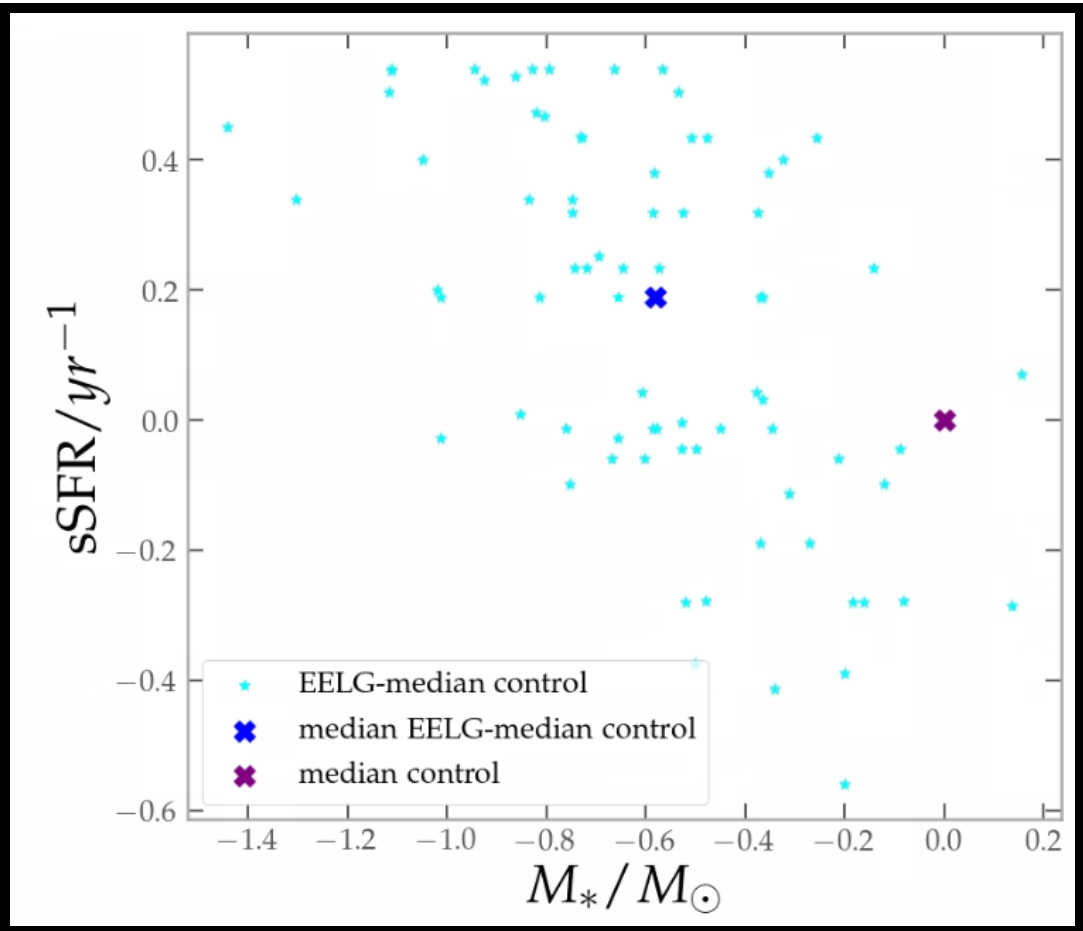
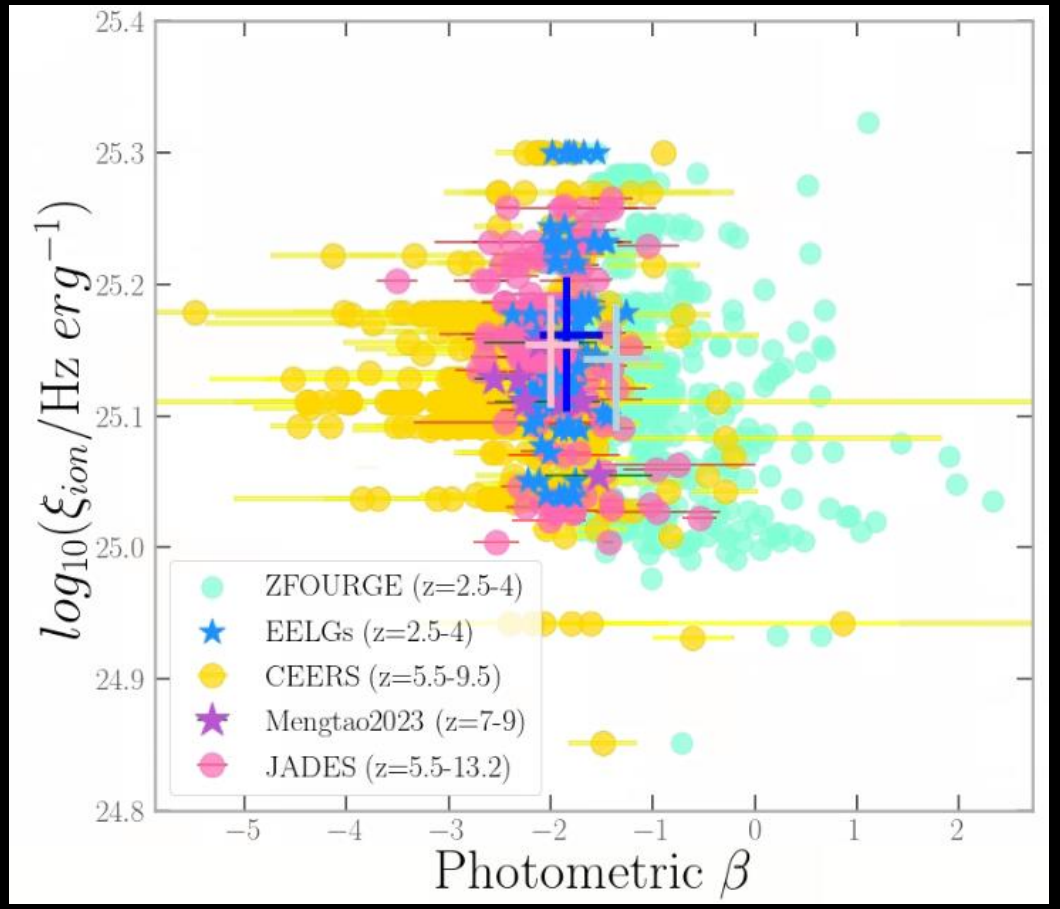
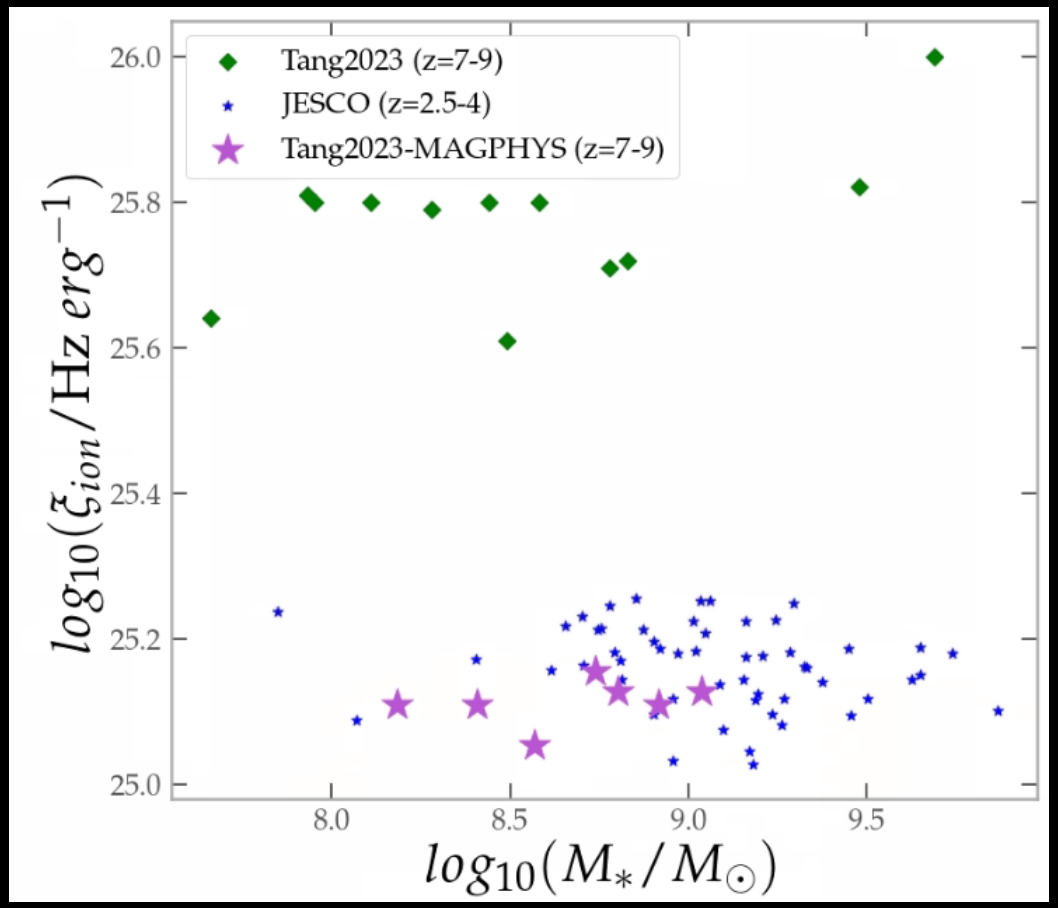






Are they analogs: Physical characteristics

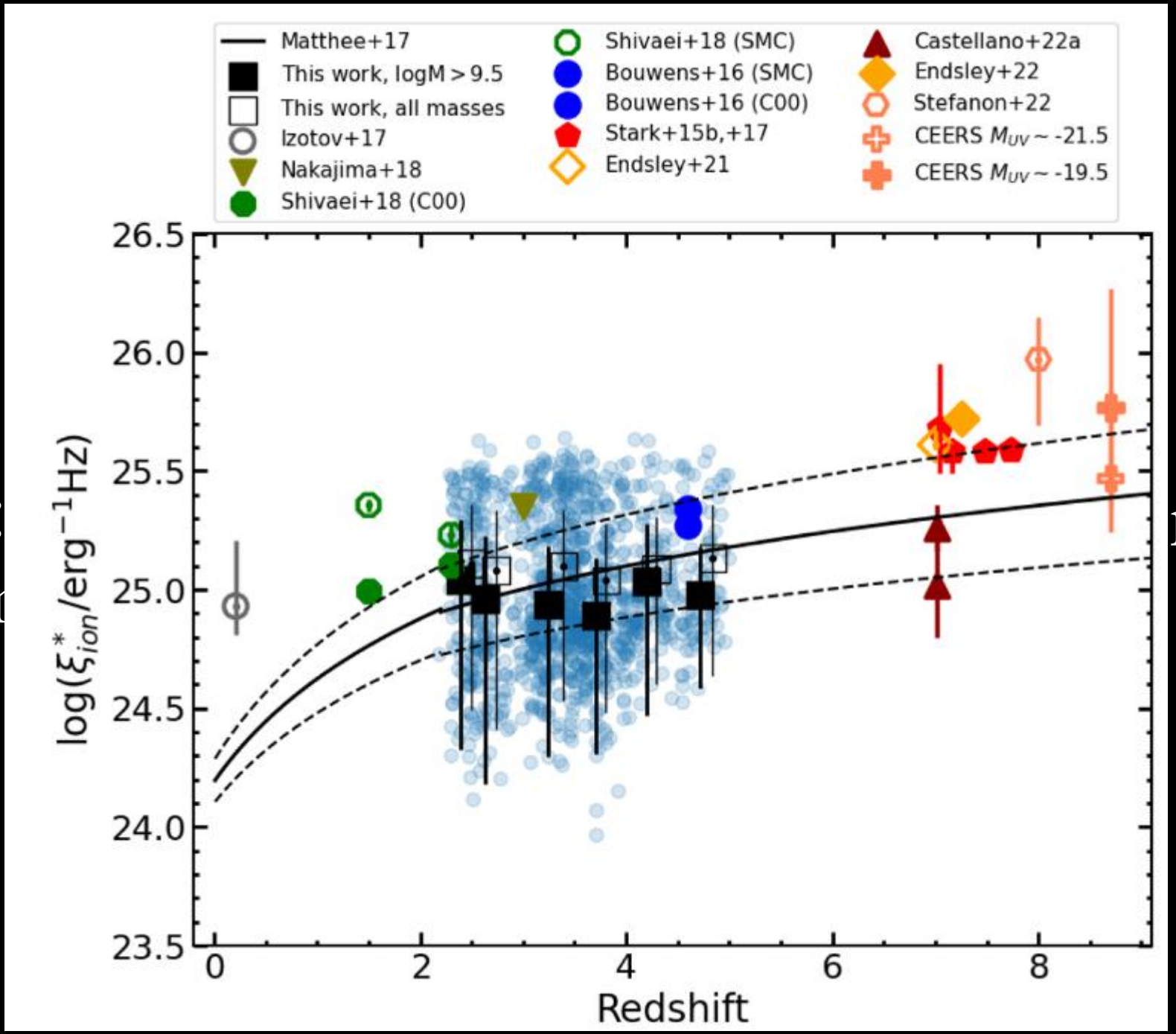




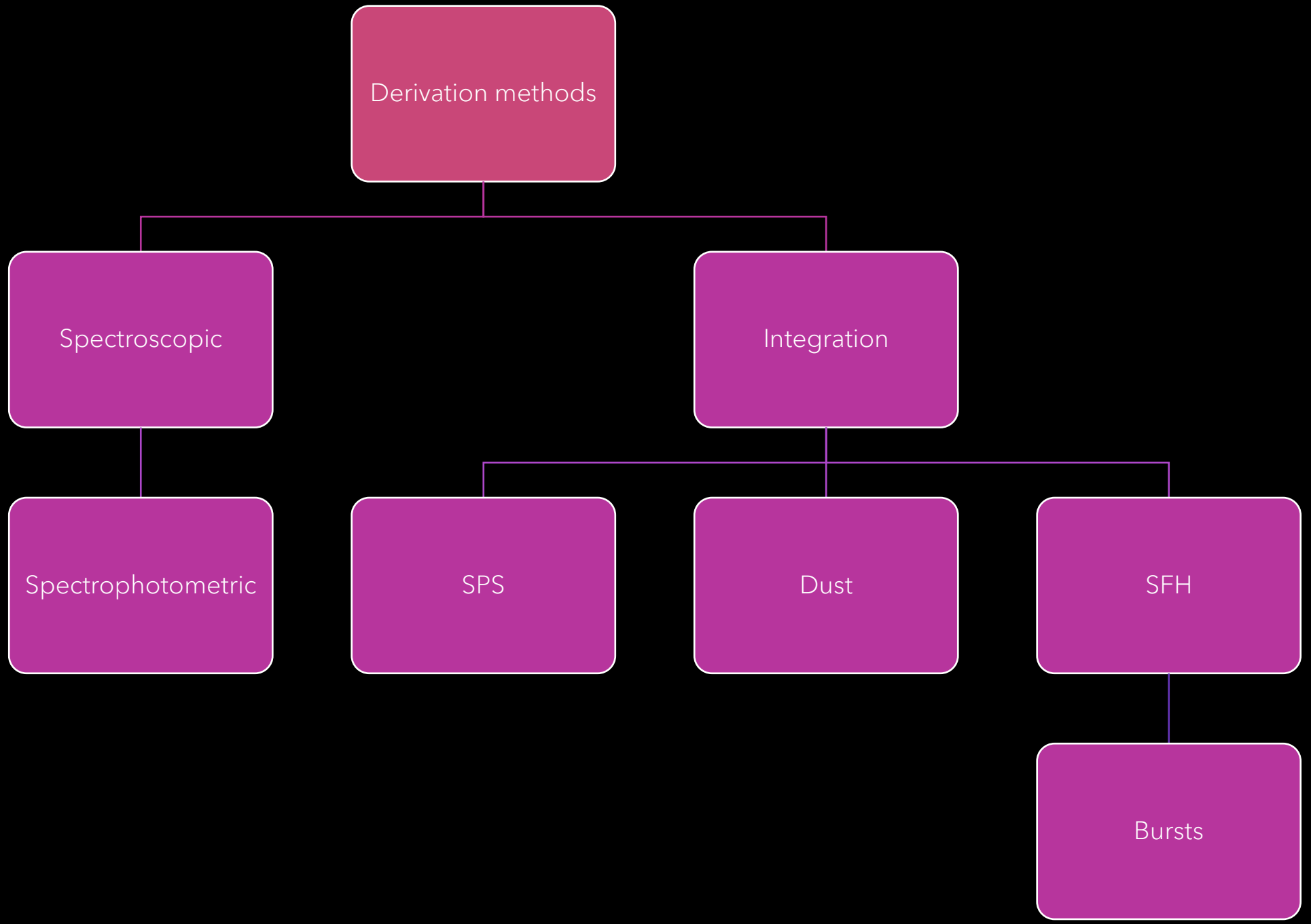
The Catalyst for this study

Arc 2: How models change galaxies. Differences in SED model assumptions

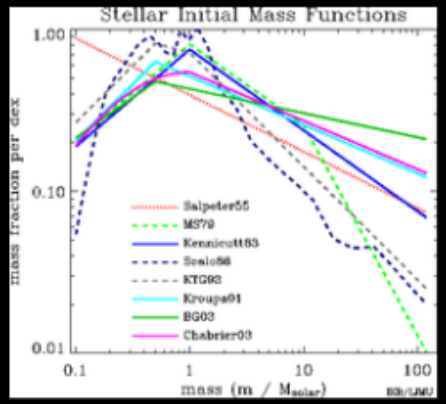
Arc 2: rences in SED m



Castellano 2023

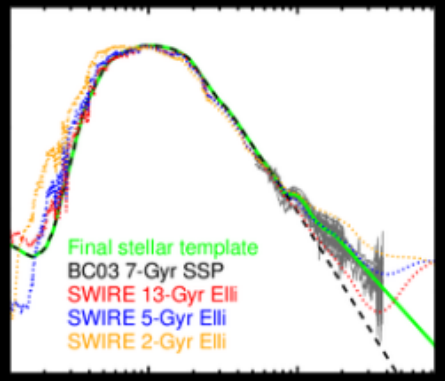

Derivation methods
Spectroscopic
Integration
Spectrophotometric
SPS
Dust
SFH
Bursts

Stellar Energy Distributions



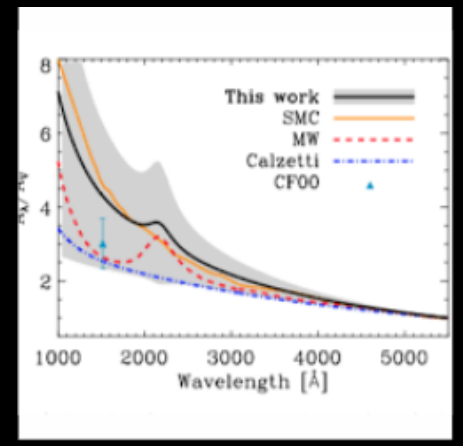
INITIAL MASS FUNCTION

Chabrier 2003



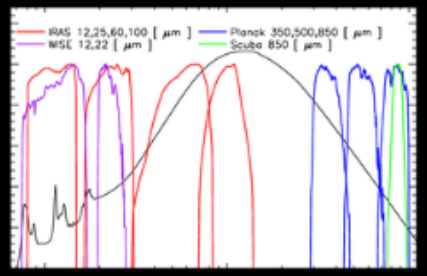
STELLAR TEMPLATE

Bruzal & Charlot 2003



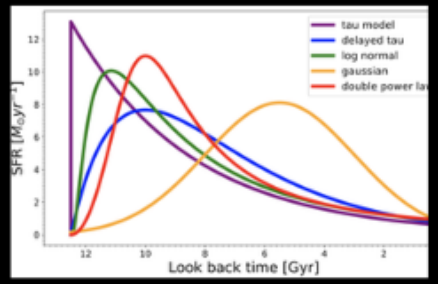
DUST ATTENUATION

Charlot & Fall 2000



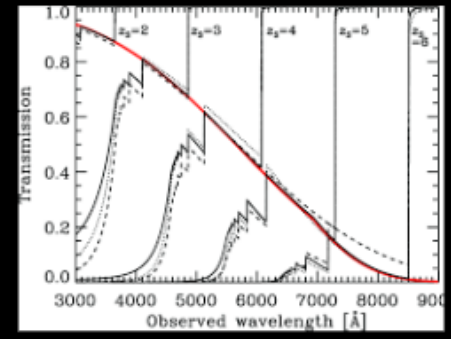
DUST EMISSION

Grey body emission



STAR FORMATION HISTORY MODEL

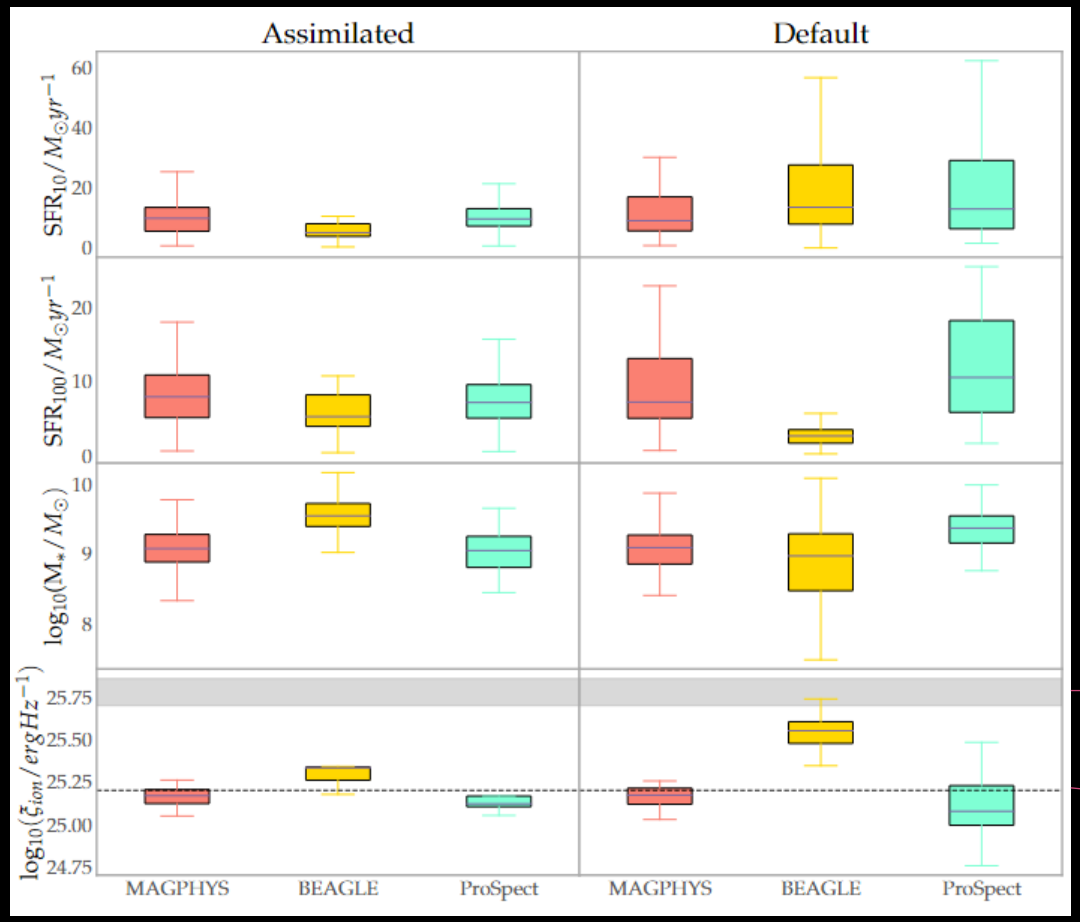
Delayed Exponential Decline



IGM ATTENUATION

Madau 1995

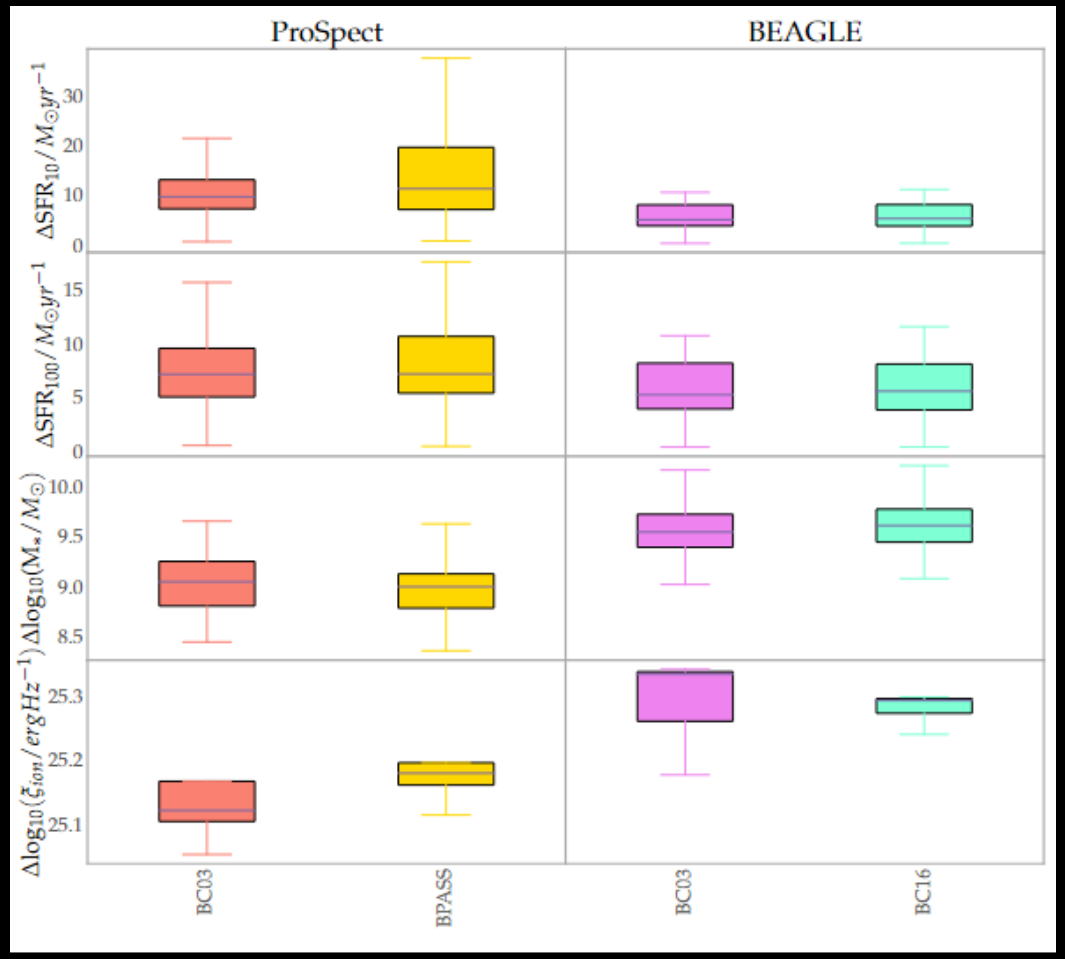
Overall Comparison



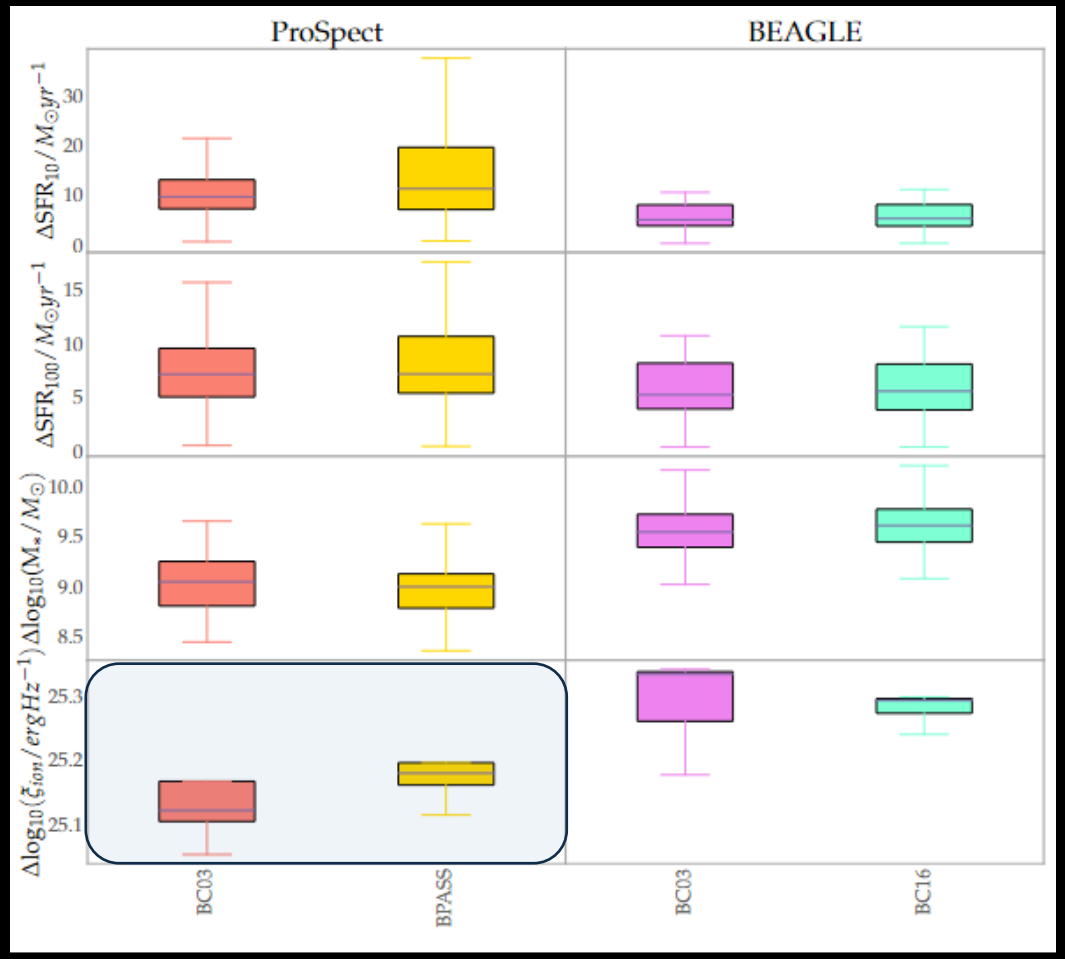
	MAGPHYS	ProSpect	BEAGLE
SFH	dτ	tsnorm	dτ+CSFH
bursts	yes	no	no
SPS	BC03	BC03	BC16
dust	CF00	CF00	intrinsic
metallicity	no	yes	yes
IGM	Madau95	None	Inoue14
emission	none	none	CLOUDY

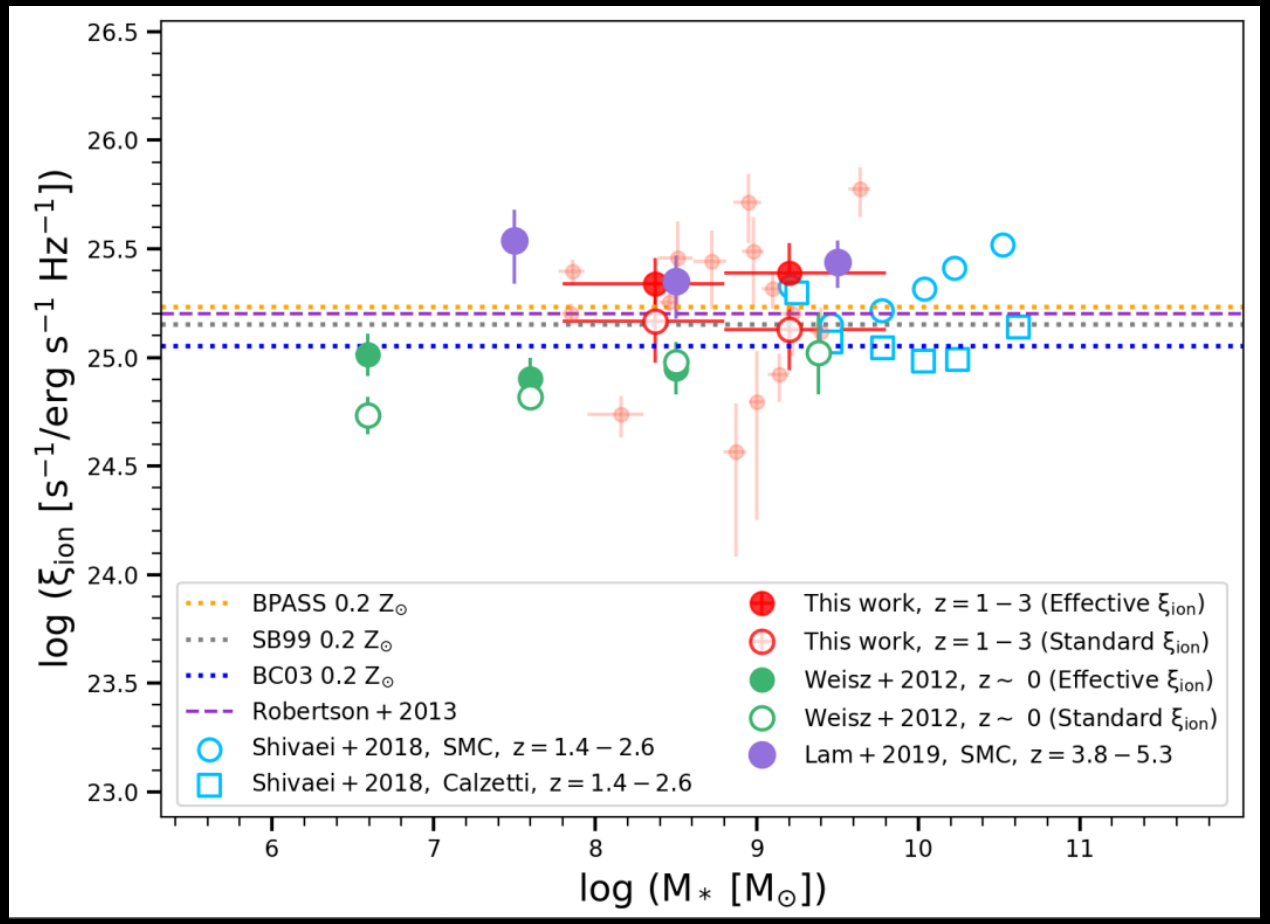
Spectroscopic values derived using BEAGLE non-ionizing UV +KMOS

Canonical value (Robertson 2012)


ProSpect
BEAGLE
$\Delta SFR_{10}/M_\odot yr^{-1}$
30
20
10
0
$\Delta SFR_{100}/M_\odot yr^{-1}$
15
10
5
0
$\Delta \log_{10}(M_*/M_\odot)$
10.0
9.5
9.0
8.5
$\Delta \log_{10}(\xi_{ion}/erg\,Hz^{-1})$
25.3
25.2
25.1
BC03
BPASS
BC03
BC16

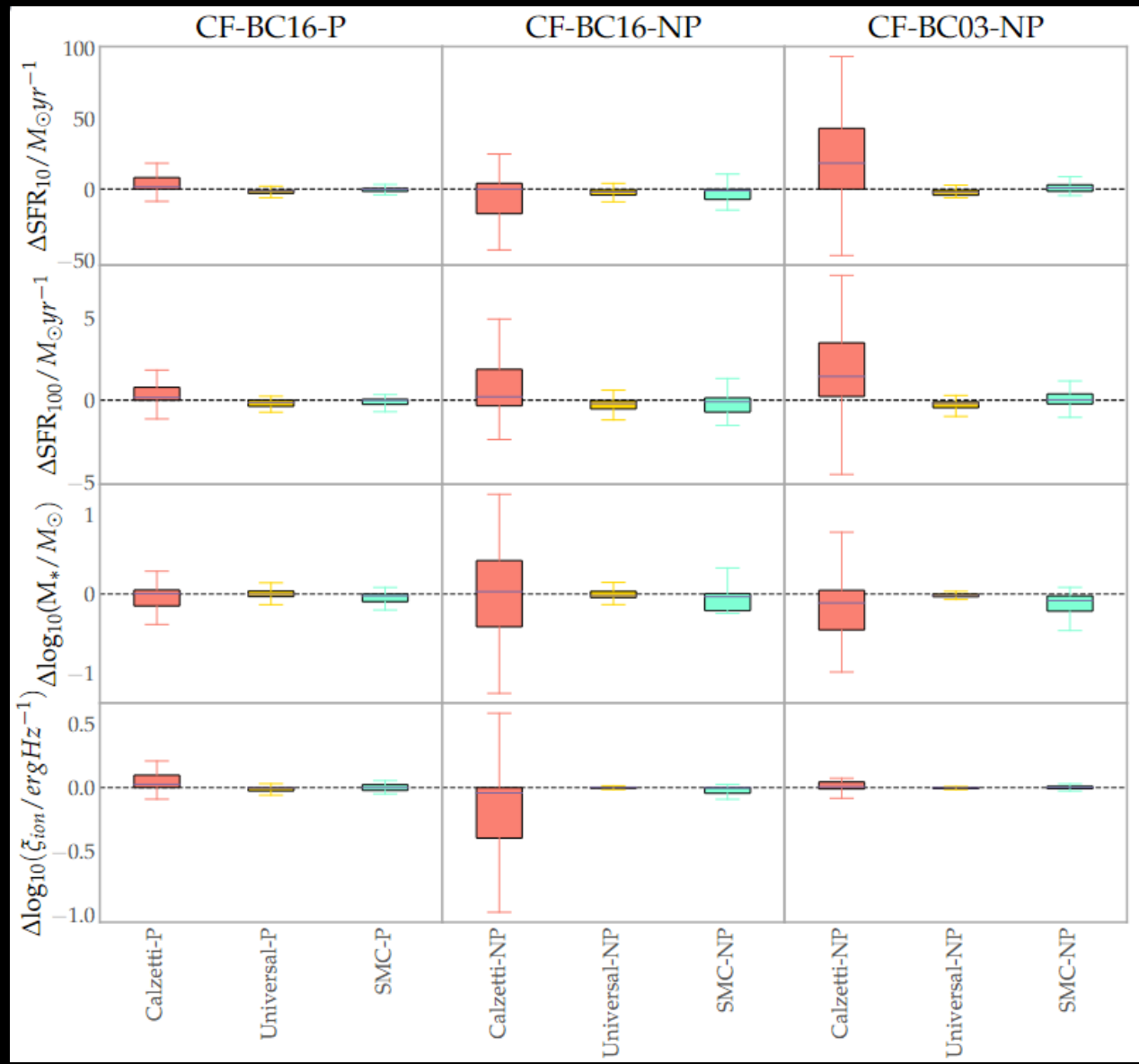
Model: SPS

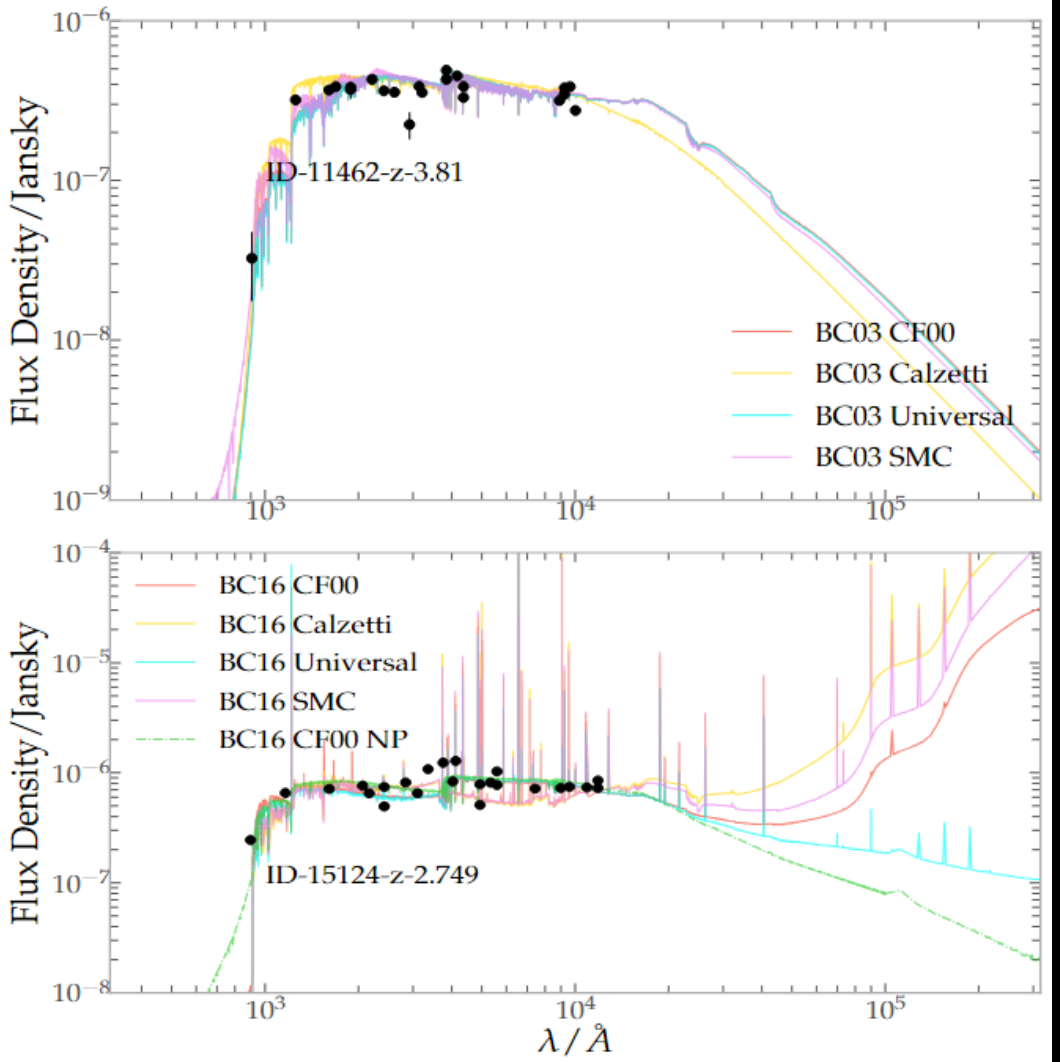


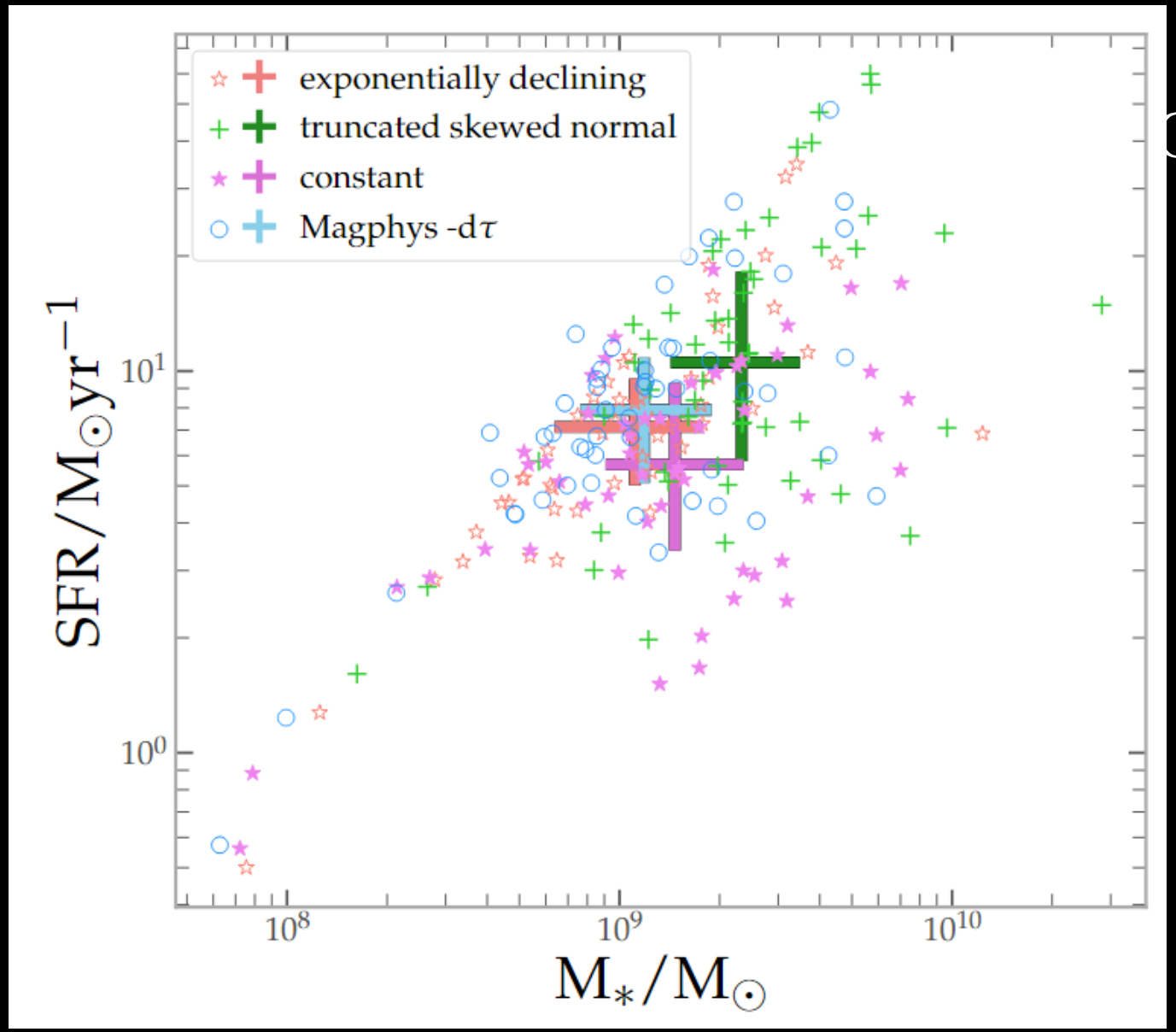


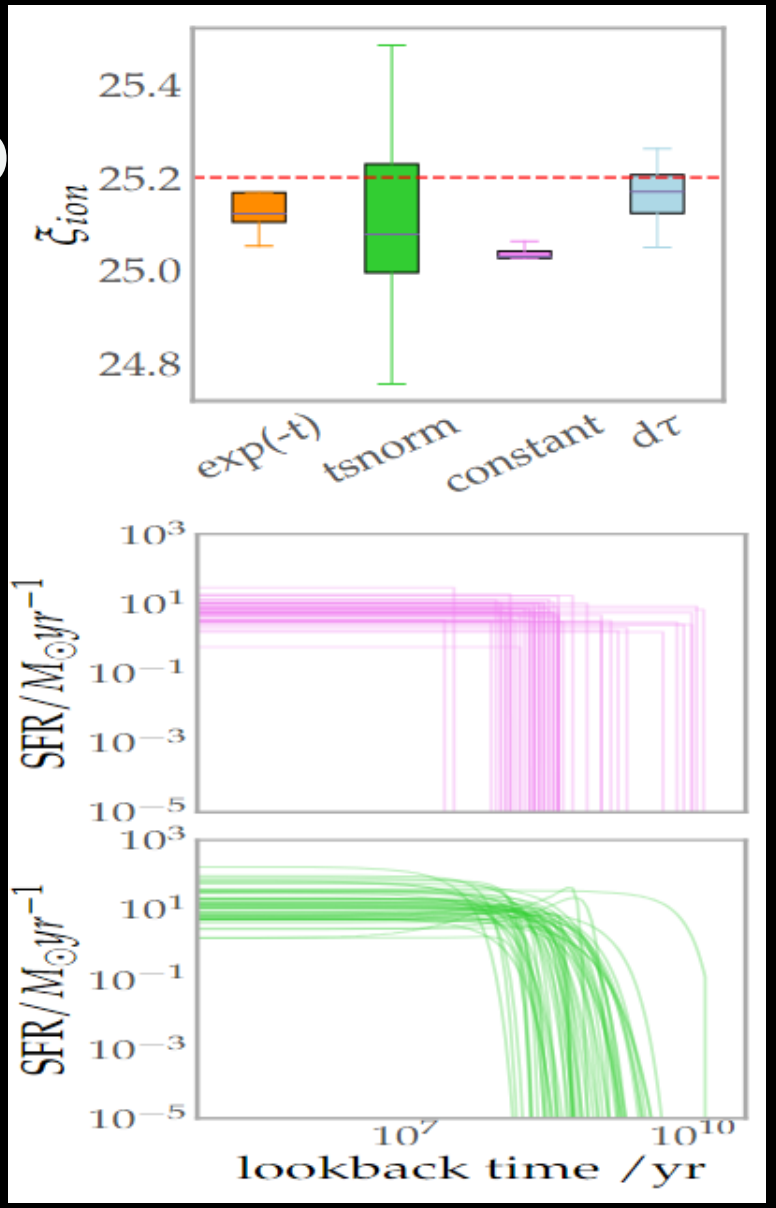
Emami 2020

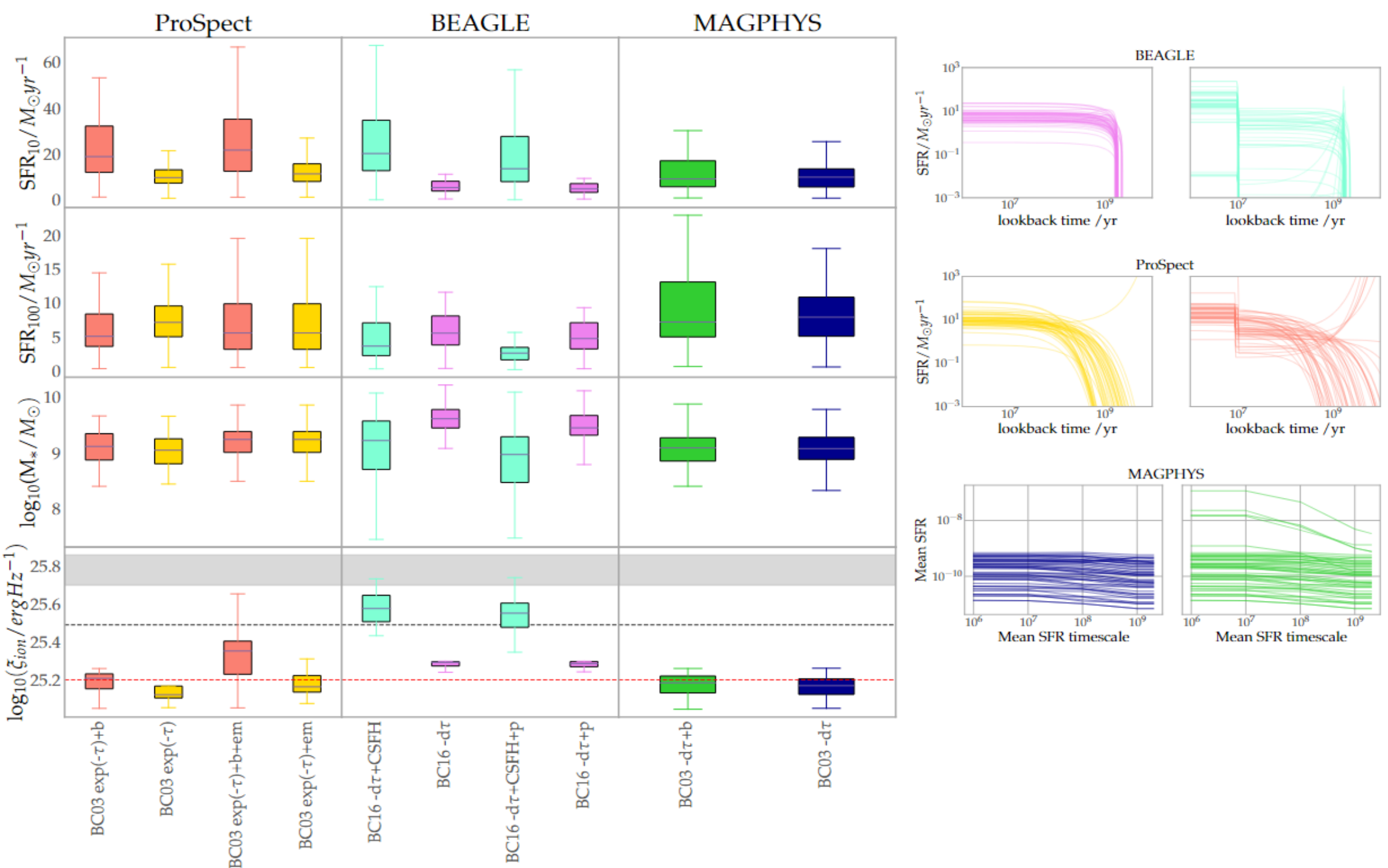
Model: SPS

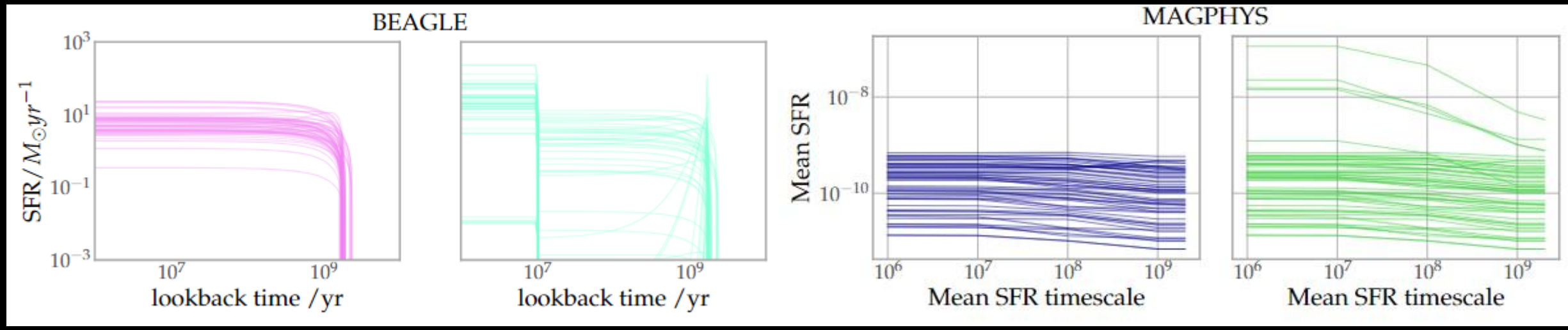

CF-BC16-P
CF-BC16-NP
CF-BC03-NP
$\Delta SFR_{10}/M_\odot yr^{-1}$
$\Delta SFR_{100}/M_\odot yr^{-1}$
$\Delta log_{10}(M_*/M_\odot)$
$\Delta log_{10}(\xi_{ion}/erg Hz^{-1})$
Calzetti-P
Universal-P
SMC-P
Calzetti-NP
Universal-NP
SMC-NP
Calzetti-NP
Universal-NP
SMC-NP

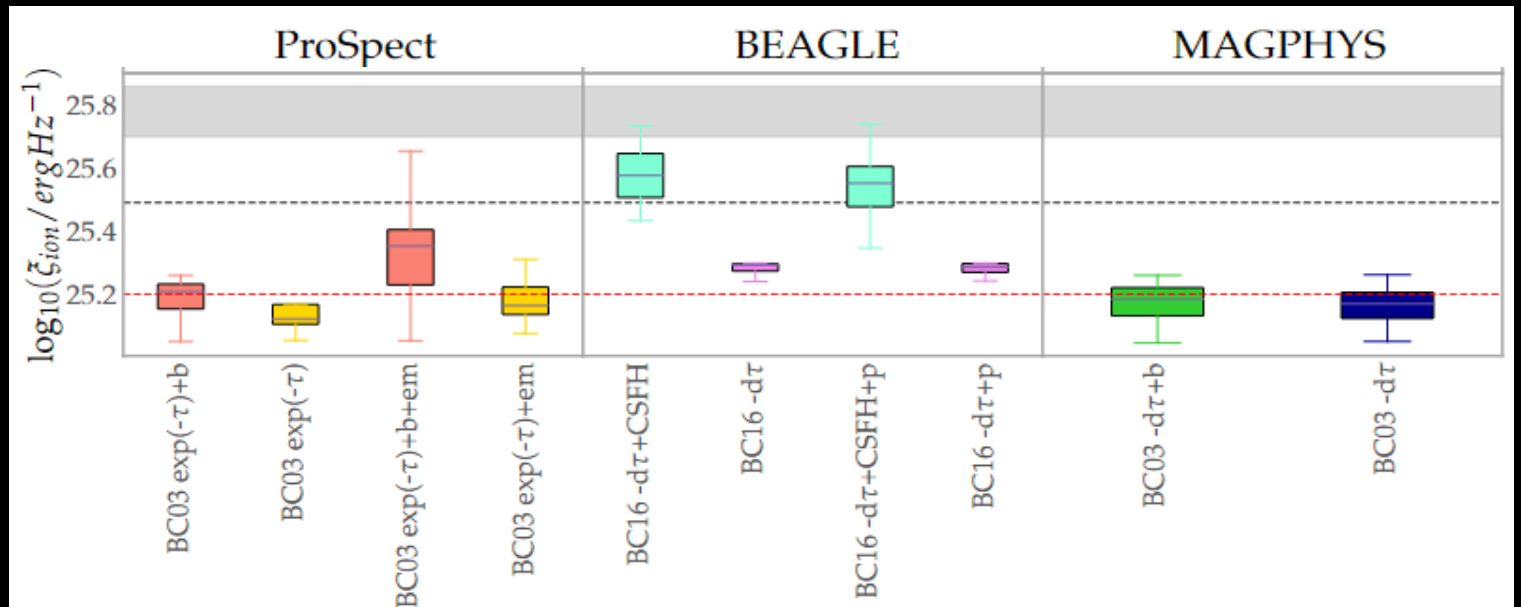

ID-11462-z-3.81
BC03 CF00
BC03 Calzetti
BC03 Universal
BC03 SMC
ID-15124-z-2.749
BC16 CF00
BC16 Calzetti
BC16 Universal
BC16 SMC
BC16 CF00 NP
Flux Density/Jansky
$\lambda/\AA$

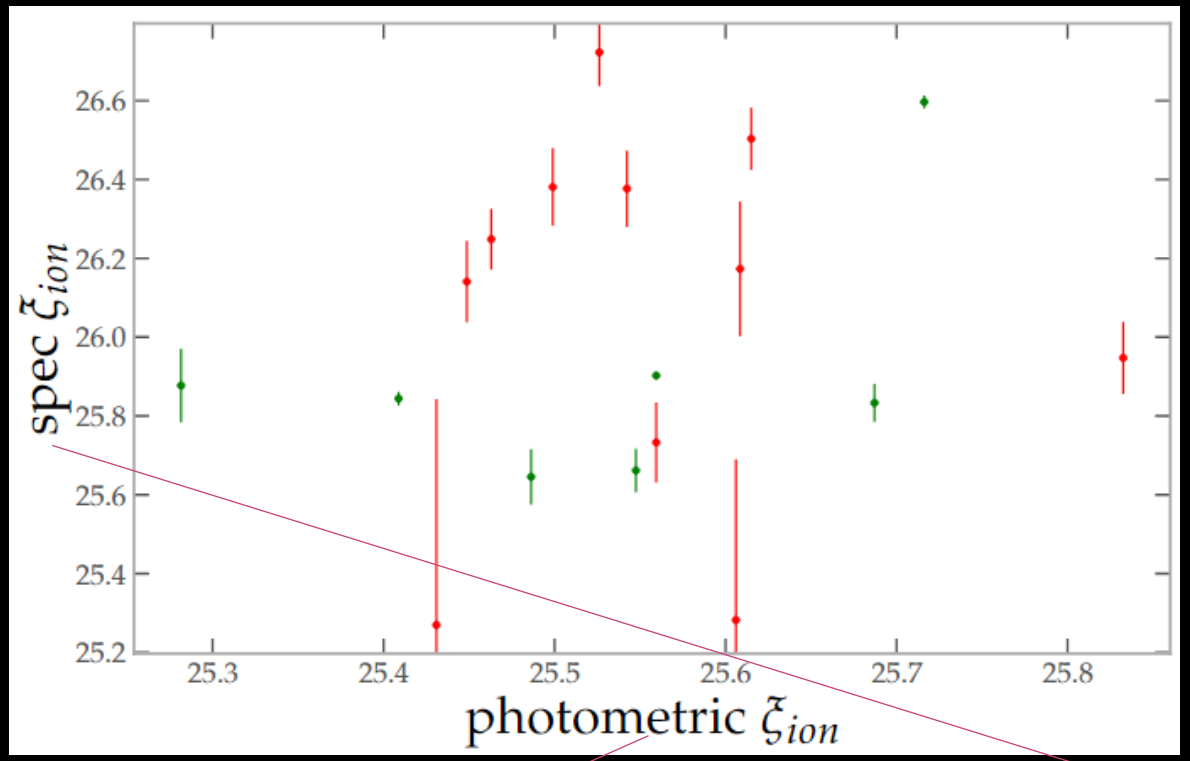

exponentially declining
truncated skewed normal
constant
Magphys -dτ
SFR/M⊙yr⁻¹
M*/M⊙


ξion
exp(-t)
tsnorm
constant
dτ
SFR/M⊙yr⁻¹
lookback time /yr


ProSpect
BEAGLE
MAGPHYS
$SFR_{10}/M_\odot yr^{-1}$
$SFR_{100}/M_\odot yr^{-1}$
$\log_{10}(M_*/M_\odot)$
$\log_{10}(\xi_{ion}/erg Hz^{-1})$
BC03 exp(-τ)+b
BC03 exp(-τ)
BC03 exp(-τ)+b+em
BC03 exp(-τ)+em
BC16 -dτ+CSFH
BC16 -dτ
BC16 -dτ+CSFH+p
BC16 -dτ+p
BC03 -dτ+b
BC03 -dτ
BEAGLE
ProSpect
MAGPHYS
$SFR/M_\odot yr^{-1}$
lookback time /yr
Mean SFR
Mean SFR timescale


BEAGLE
MAGPHYS
SFR / $M_\odot yr^{-1}$
10^3
10^1
10^{-1}
10^{-3}
10^7
10^9
lookback time /yr
Mean SFR
10^{-8}
10^{-10}
10^6
10^7
10^8
10^9
Mean SFR timescale


ProSpect
BEAGLE
MAGPHYS
$\log_{10}(\xi_{ion} / erg Hz^{-1})$
25.8
25.6
25.4
25.2
BC03 exp(-τ)+b
BC03 exp(-τ)
BC03 exp(-τ)+b+em
BC03 exp(-τ)+em
BC16 -dτ+CSFH
BC16 -dτ
BC16 -dτ+CSFH+p
BC16 -dτ+p
BC03 -dτ+b
BC03 -dτ



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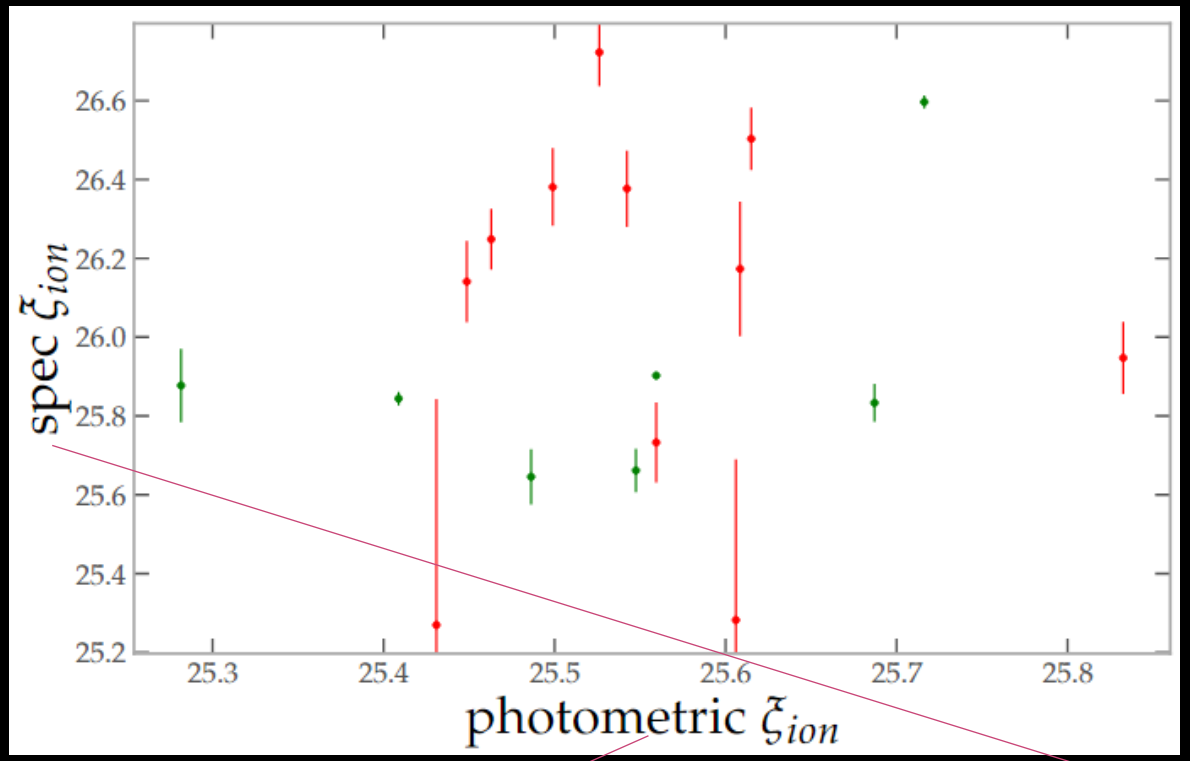
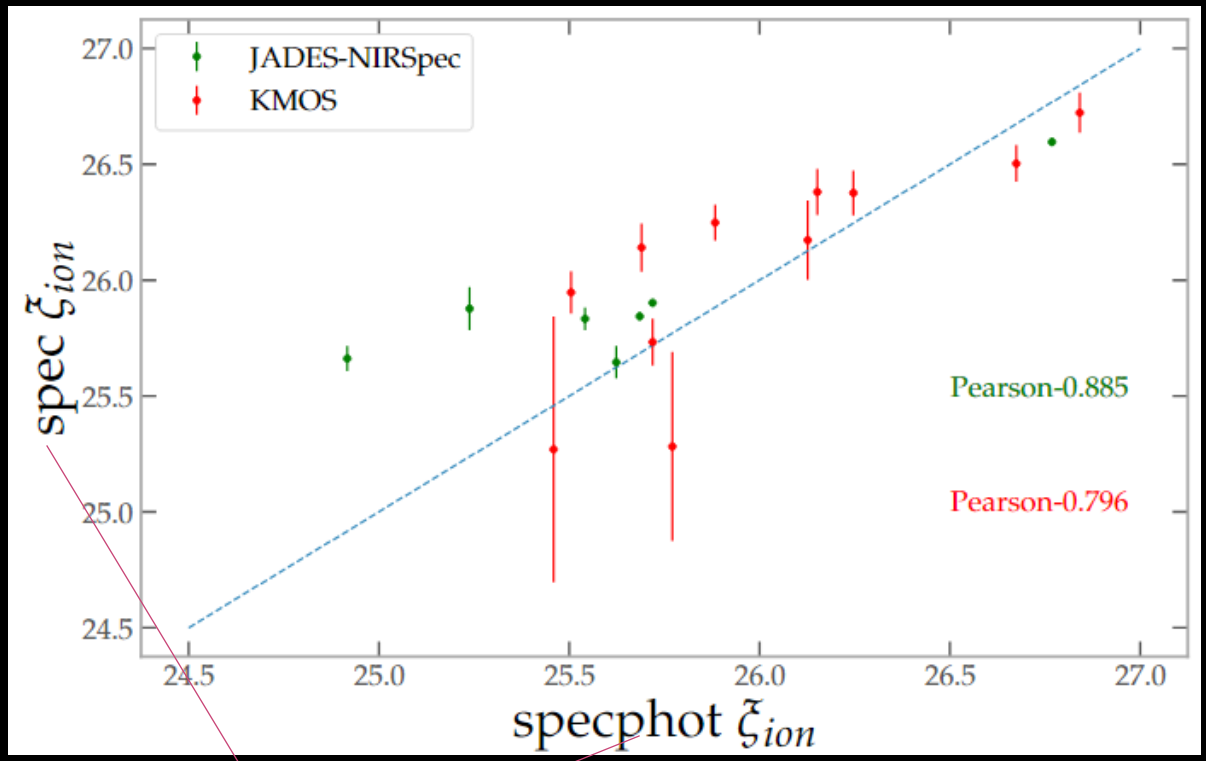
$$\xi_{ion} = \frac{N(H_\alpha)}{L_{UV}} = \frac{N(H_\beta)}{L_{UV} \times c_{rec}}$$

Other methods





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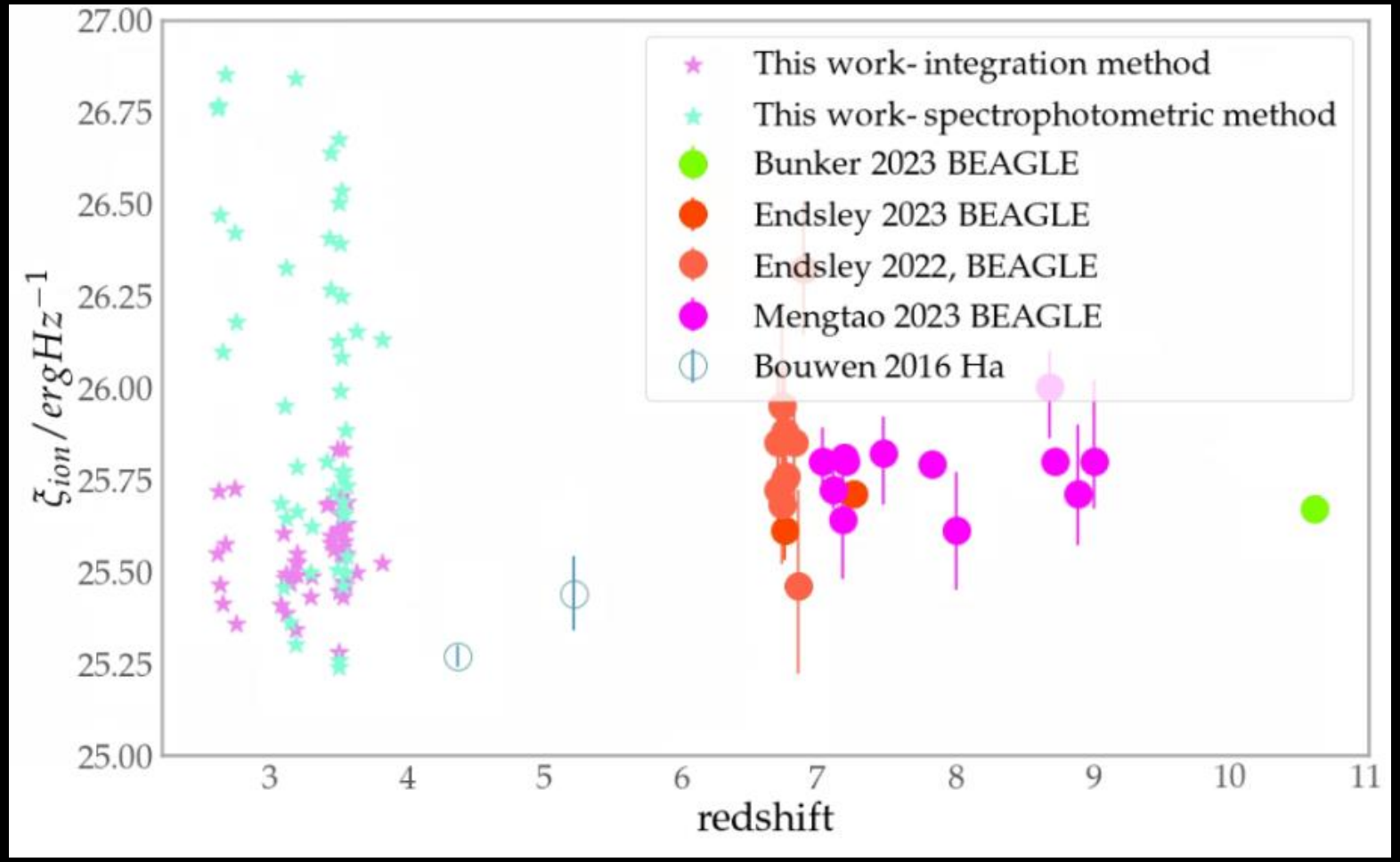
Other methods

The Redshift Evolution Question



Conclusions

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Which models to use, when to use

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My PhD is ending this is a you problem

Conclusions

Which models to use, when to use

My PhD is ending this is a you problem

Pay me to care (any Postdocs?)