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SCALING RELATIONS OF STELLAR POPULATIONS IN THE LOCAL UNIVERSE

ID: 234

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SCALING RELATIONS

The evolution of galaxies is driven by a combination of complex mechanisms such as the assembly of dark matter structures, gas dynamics, star formation, and feedback from both stars and AGN. These processes produce systematic variations among different galaxy properties, such mean stellar ages and metallicities. The relations that link these properties with stellar mass are generally known as scaling relations. On one hand the **Mass-Age** relation can help us understand the quenching mechanism, on the other the **Mass-Metallicity** encodes **fundamental information about the baryon cycle**. Therefore, having a reliable assessment of scaling relations is crucial to study galaxy evolution.

Using **updated models for Stellar Population Synthesis and novel analysis of SDSS DR7** dataset, we **revise** the Mass-Age and Mass-(stellar) Metallicity relations by Gallazzi et al. (2005) (Fig. 1). We show that both models and data improvements have a **substantial impact on the resulting scaling relations**.

OBSERVATIONAL DATA

The dataset used in this work is composed by **photometric and spectroscopic** observations of **825,263** galaxies drawn from the **SDSS DR7** (Abazajian et al. 2009). Photometry is obtained in the five **ugriz bands**, while spectroscopic observations are carried out using 3" diameter aperture optical fibers. The obtained spectra cover the wavelength range 3800 − 9200 Å, with an average spectral resolution R = λ/Δλ = 2000.

From the spectrum of each galaxy a set of 39 **absorption indices** was measured (Brinchmann et al. 2004).

To carry out our Stellar Population analysis we selected the following indices:

Age sensitive
Worthey (1994),
Worthey & Ottaviani (1997)

- D4000n
- Hβ
- Hγ+Hδ

- [MgFe]'
- [Mg2Fe]

Metallicity sensitive
Thomas et al. (2003)
Bruzual & Charlot (2003)
(indipendent on [α/Fe])

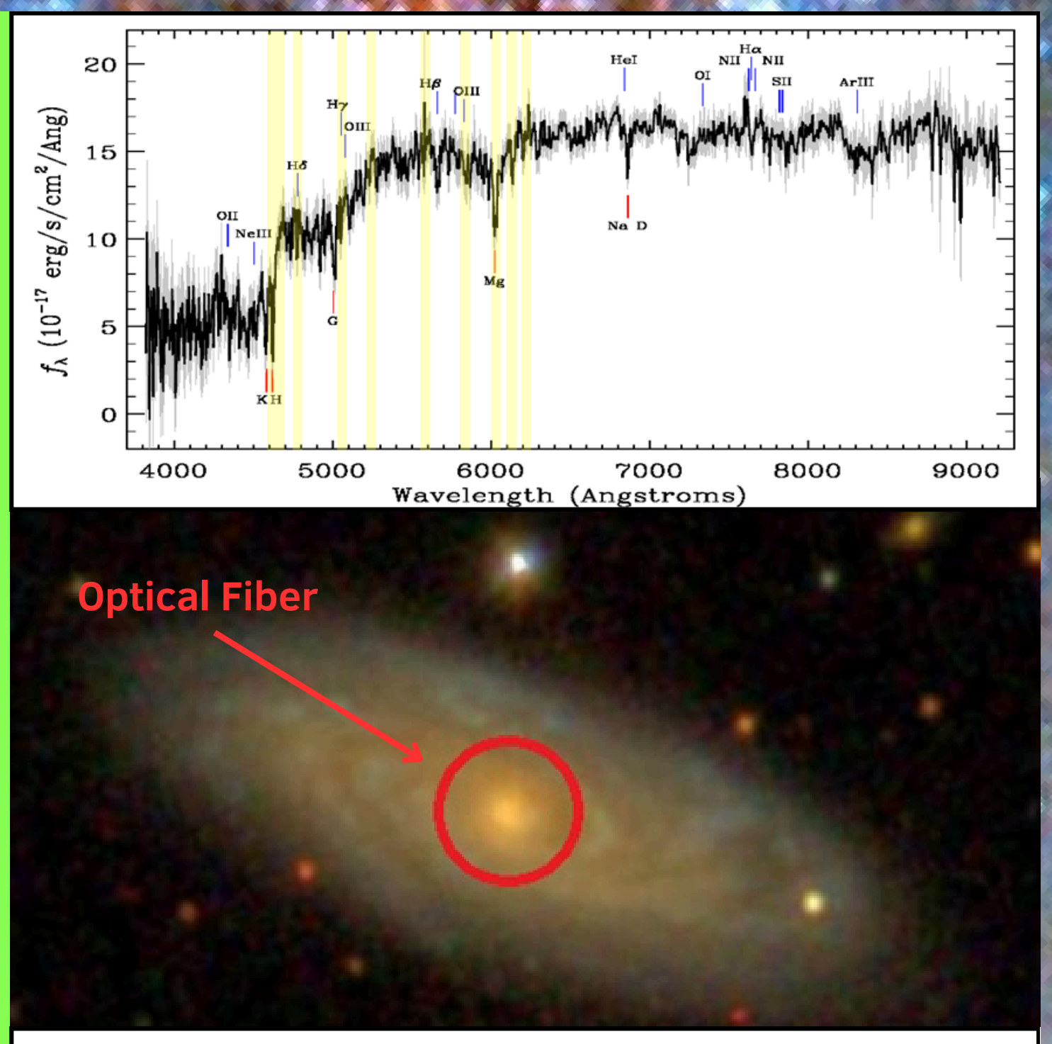


Fig. 2: SDSS galaxy with the projected optical fiber used to extract the spectra

With respect to Gallazzi et al. (2005) we included:

- ***STATISTICAL CORRECTIONS***:
  - obtain a **volume limited** sample
  - correct for the biases induced by galaxy selection criteria during the analysis
- ***APERTURE EFFECT CORRECTIONS:***
  - Corrections to the indices estimations to compensate for light loss from the outer regions of galaxies, caused by the aperture of the optical fibers (Fig. 2), and stellar population gradients

Calculated by Zibetti, Pratesi et al. (in prep.) using **IFU** observations of 394 **CALIFA** galaxies

INFERENCE

The inference of stellar population properties was made using the **BaStA bayesian spectral inference code** from Zibetti et al. (2017), developed from the work in Gallazzi et al. (2005) and Kauffmann et al. (2003). The prior distribution consisted in a library of **500 000 Composite Stellar Populations** (Fig. 3), obtained combining Simple Stellar Populations (Bruzual & Charlot 2003), Star Formation Histories, Chemical Enrichment Histories, and dust absorption (see Zibetti et al. 2017).

For each galaxy in the sample, we estimated the pdf for stellar population parameters such as the **present day stellar mass, the light-weighted and mass-weighted mean stellar ages and metallicities, and dust absorption.** This was done by estimating the **likelihood** of each CSP, by **comparing the absorption indices and ugriz photometry** extracted from SDSS observations, directly **with the models**.

We then obtained the best estimate for the galaxy properties as the median of the pdf and the uncertainties as the 16th and 84th percentiles.

With respect to Gallazzi et al. (2005) we introduced **improvements in the modeling** in the following recipes:

	OLD	NEW
dust treatment:	Colour Excess	Attenuation (Charlot & Fall 2000)
stellar library:	STELIB (Le Borgne et al.2003)	MILES (Sanchez-Blazquez et al. 2006)
evolutionary tracks:	Padova94 (Fagotto et al. 1994)	PARSEC (Bressan et al. 2012)
Star Formation Histories (continuous + **bursts**):	Decaying Exponential + bursts	Delayed gaussian (Sandage 1986) + bursts
Chemical Evolution History:	Constant	Evolving (w Mstar) (Zibetti et al. 2017)

MODEL CHANGES

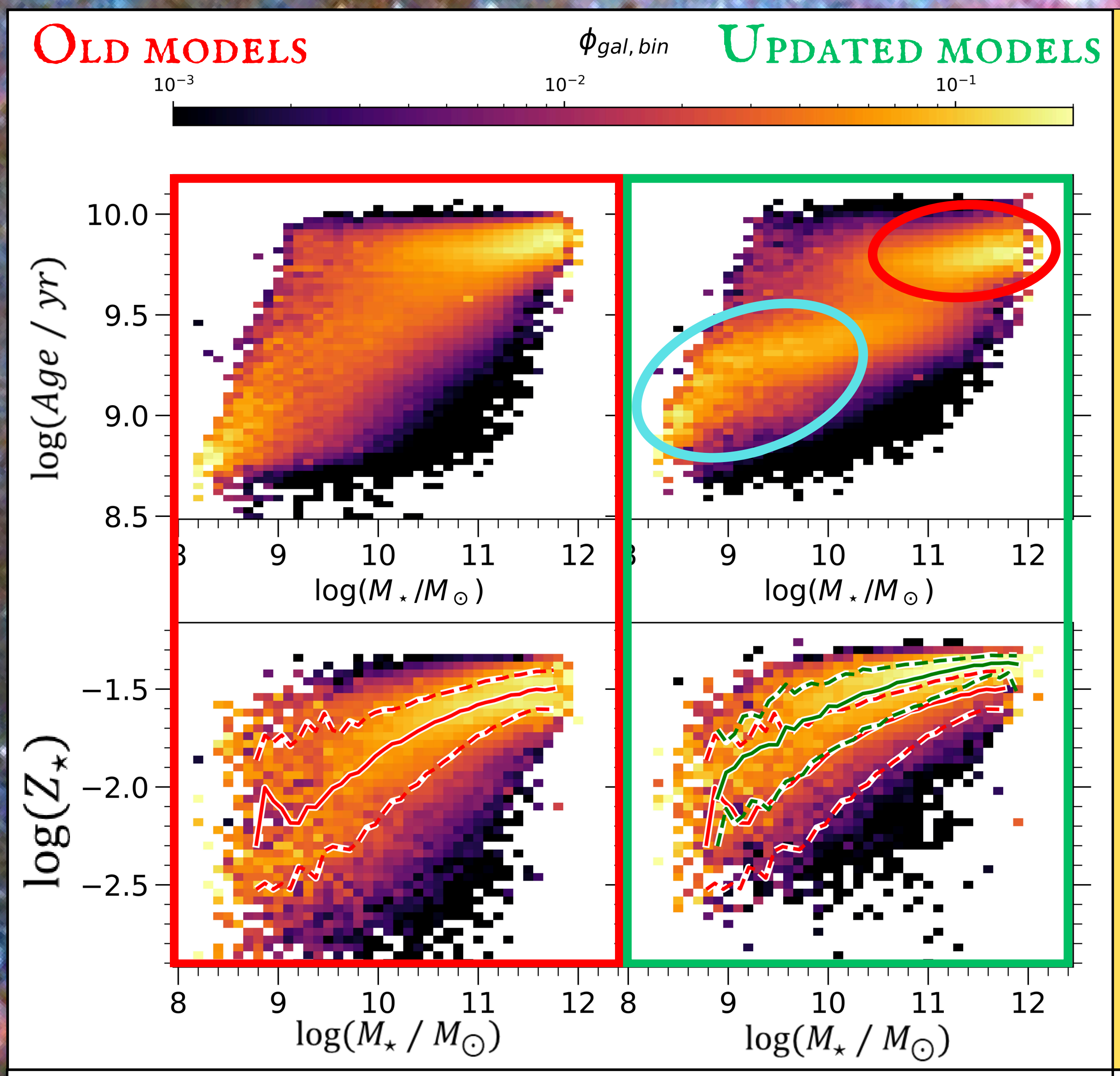


Fig. 4: Density maps for the SDSS DR7 galaxy sample. The solid lines identify the medians, while the dashed ones the 16th and 84th percentiles (*old*, *new*). In the Mass-Age plane we clearly see that the updates in the models lead to the formation of a **bimodal distribution**, while in the Mass-Metallicity we see a mean **shift** of 0.2 dex towards **higher metallicities**.

APERTURE CORRECTIONS

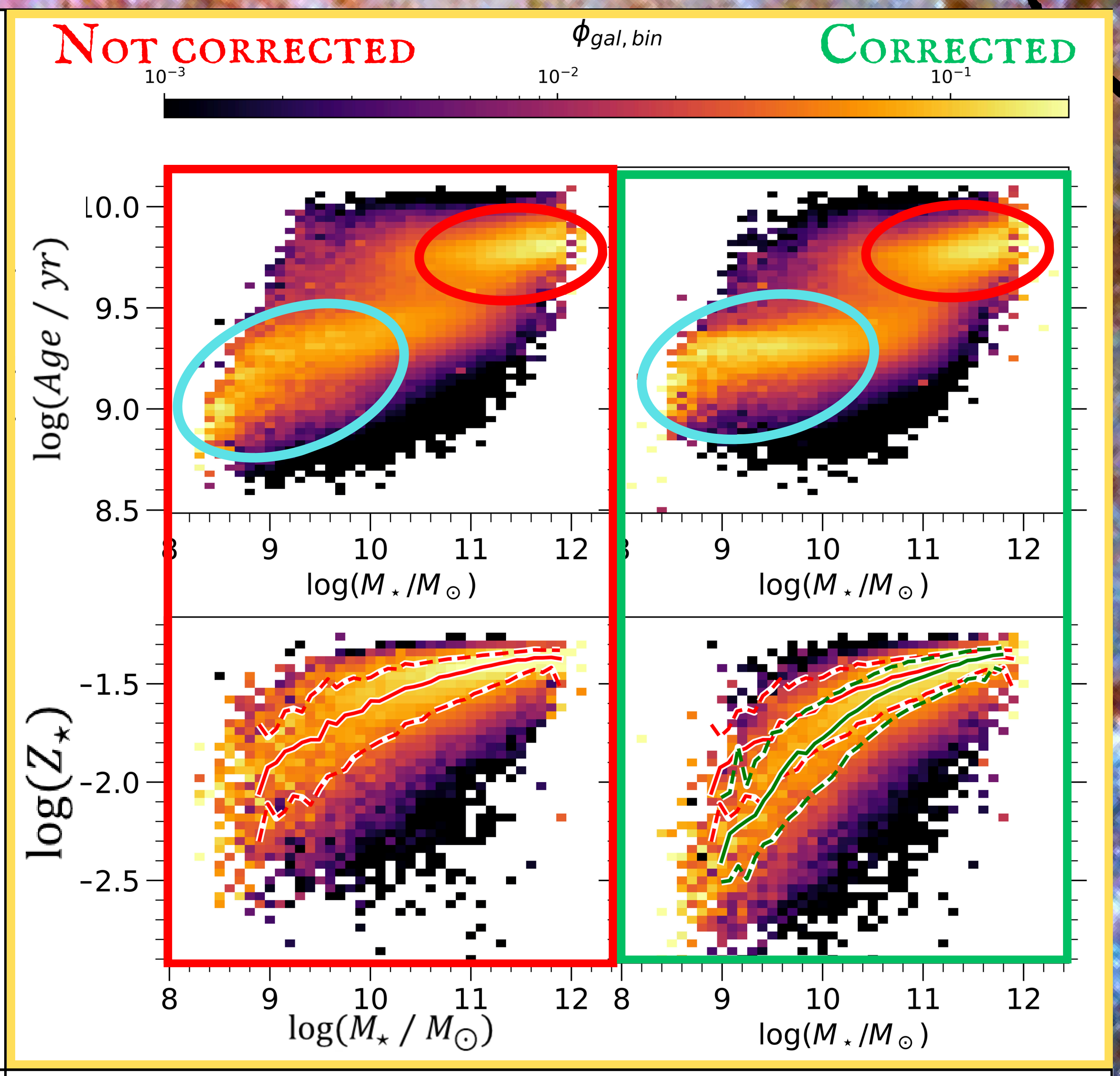


Fig. 5: Density maps for the SDSS DR7 galaxy sample. The solid lines identify the medians, while the dashed ones the 16th and 84th percentiles (*old*, *new*). In the Mass-Age plane we see that the corrections lead to the **shift** of galaxies **from the passive sequence to the young one**, while in the Mass-Metallicity we see a **mass-dependent shift** towards **lower metallicities**.

CONCLUSIONS

MODEL CHANGES: (*Fig. 4*)

- Formation of a **bimodal distribution** in the **Mass-Age** plane
- **Shift** towards **higher metallicities**

Primarily *caused* by the change of the **continuous component** for the Star Formation History from a decaying exponential to a delayed gaussian, which presents a phase with an **increasing Star Formation Rate**

Primarily *caused* by the introduction of an **increasing metallicity phase** with the formed stellar mass, with respect to the constant one in Gallazzi et al. 2005

APERTURE CORRECTIONS: (*Fig. 5*)

- Shift of galaxies **from the old sequence to the young one**
- **Mass dependent decrease of the metallicity**

The aperture corrections account for the light lost from the stellar populations in the **outer parts** of a galaxy, which are generally **younger and more metal poor** than the central ones

STATE OF THE ART

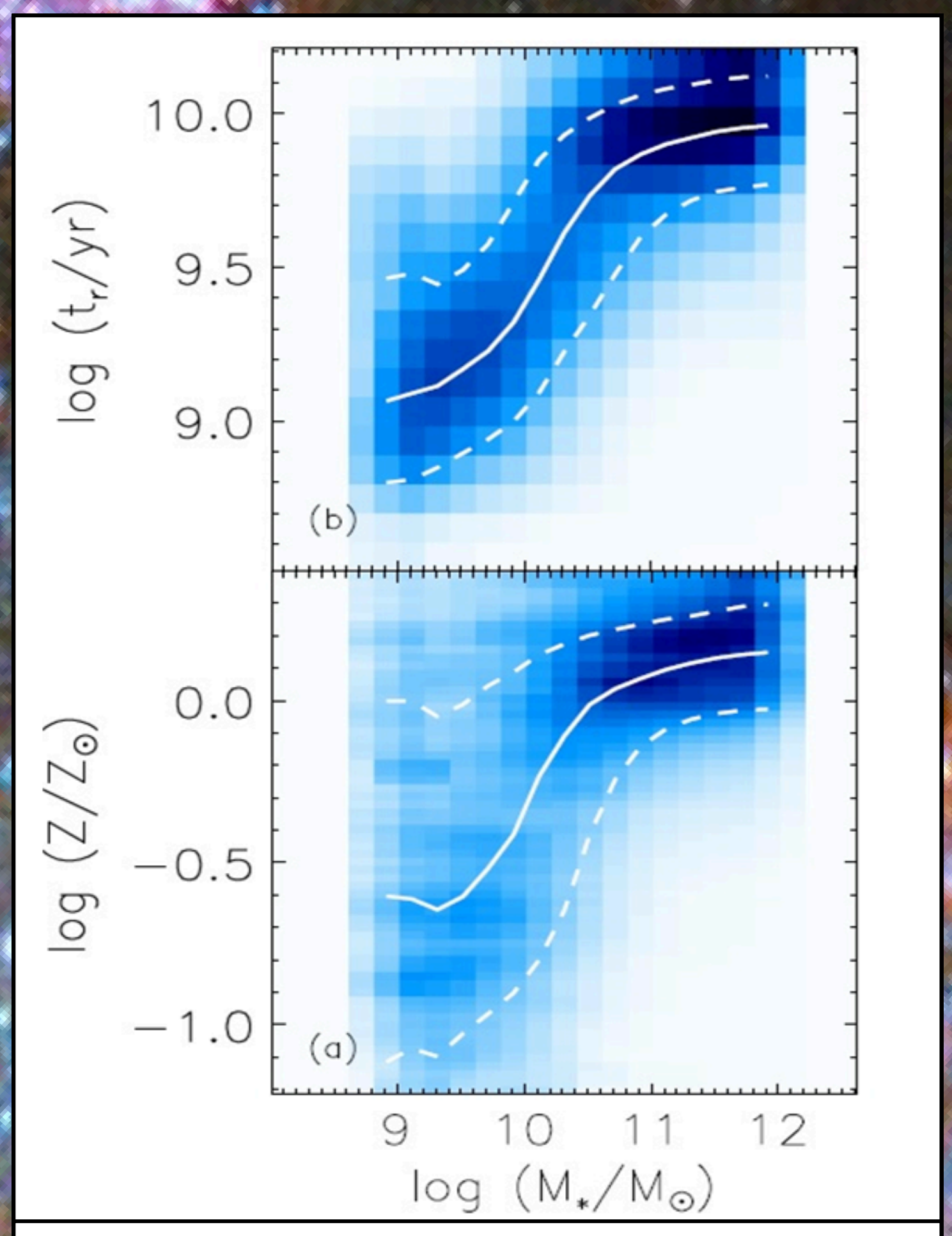
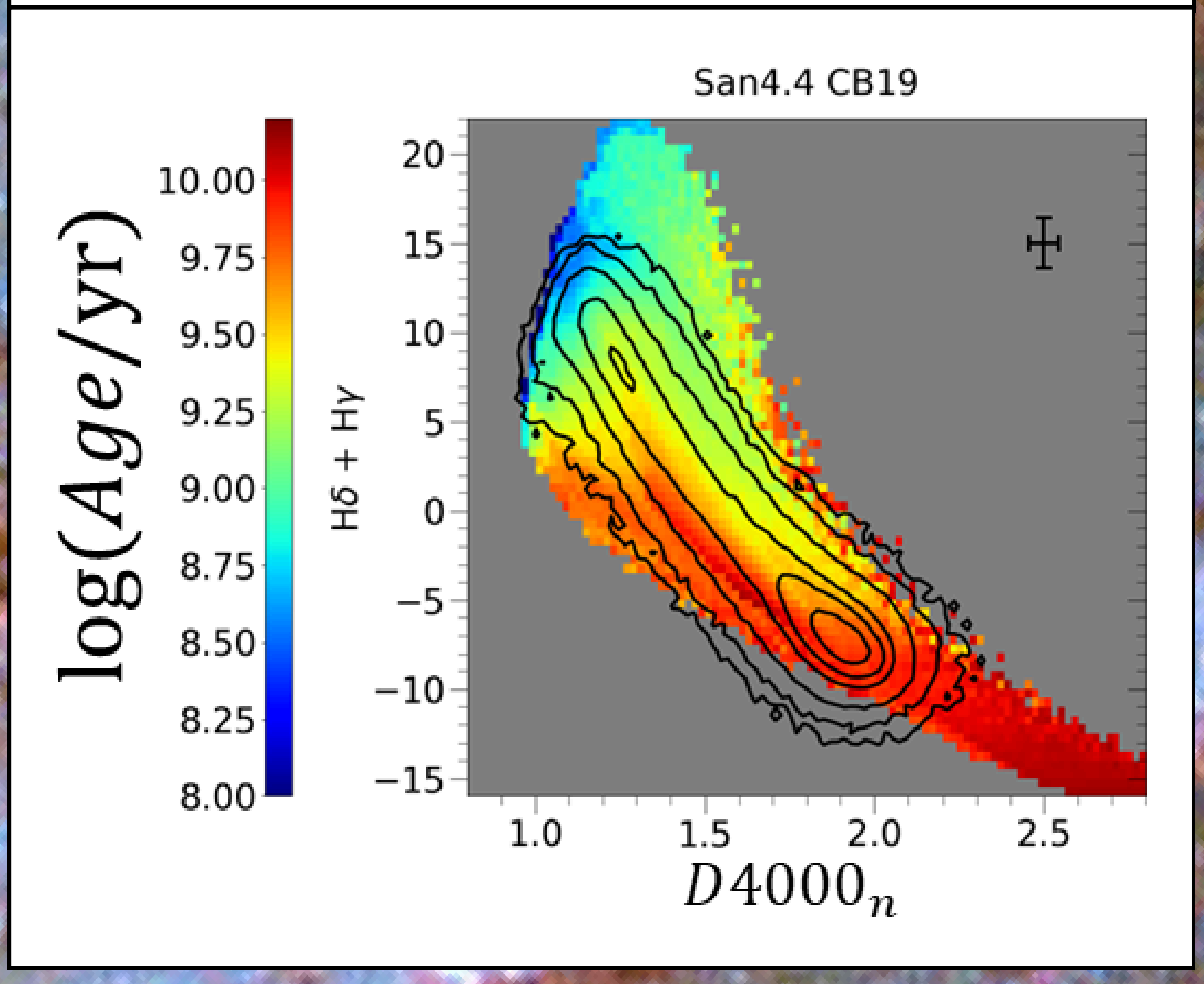
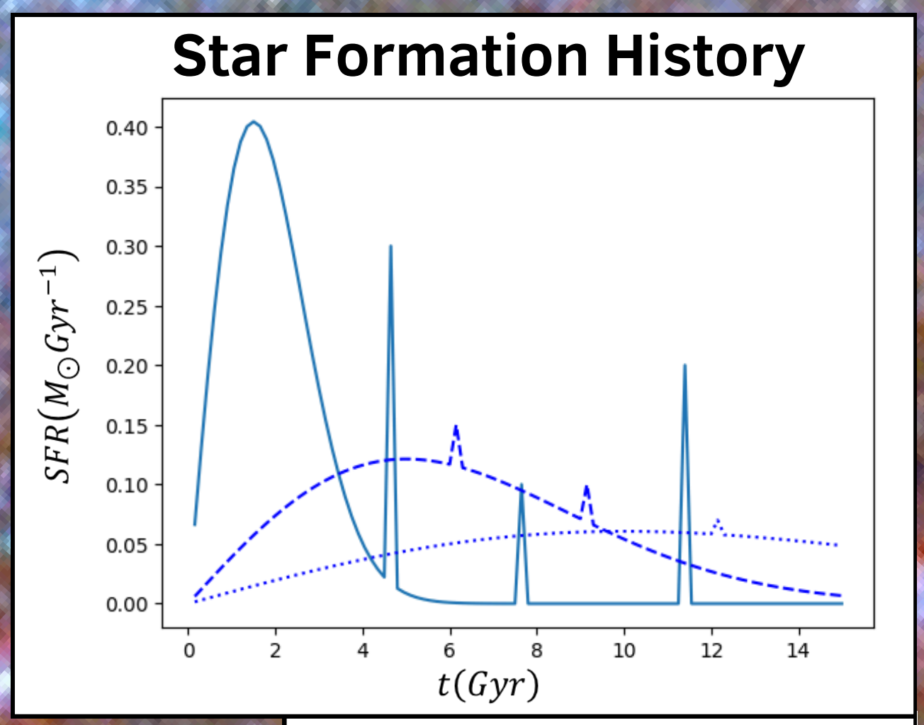
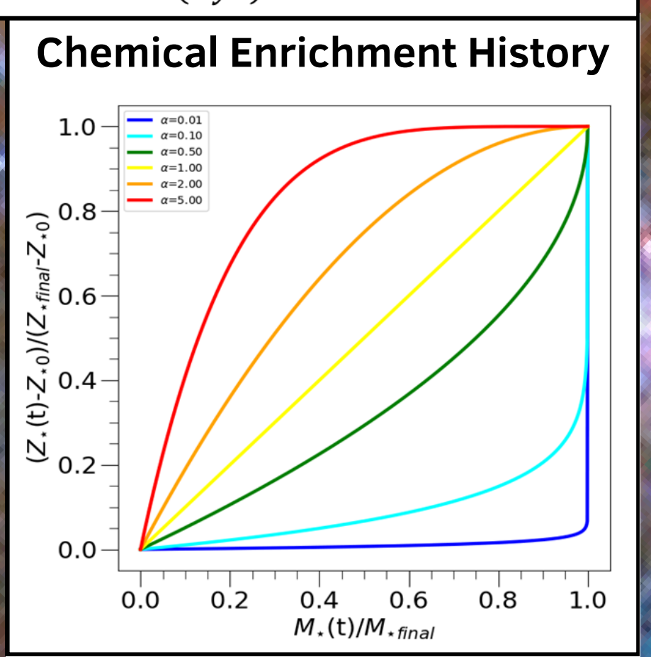


Fig. 1: Mass Age and Mass (stellar) Metallicity scaling relations by Gallazzy et al. (2005).

Fig. 3: CSP library in the Hγ+Hδ Vs D4000n plane, color coded by the median age of the stellar populations. The contours represent the distribution in the plane of the SDSS galaxies used in this work







UPDATED MODELS

FUTURE DEVELOPEMENTS

We plan to expand this work on stellar population scaling relations in the following ways:

- Use these corrected scaling relations to **quantify the evolution of stellar population parameters** through different cosmic epochs
- Use measurements of the Star Formation Rate to analyse **separately star forming and passive galaxies**. This could shed light on quenching mechanism (Trussler et al. 2020) and its dependence on galaxy structure (Zibetti & Gallazzi 2022)
- Use **upcoming data** from WEAVE-StePS to fill the redshift gap between SDSS (z=0.1) and LEGA-C (z=0.8)

Furthermore such scaling relations will be the **reference for theoretical models** of galaxy evolution.

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