On the accurate assessment of the stellar properties of EELGs

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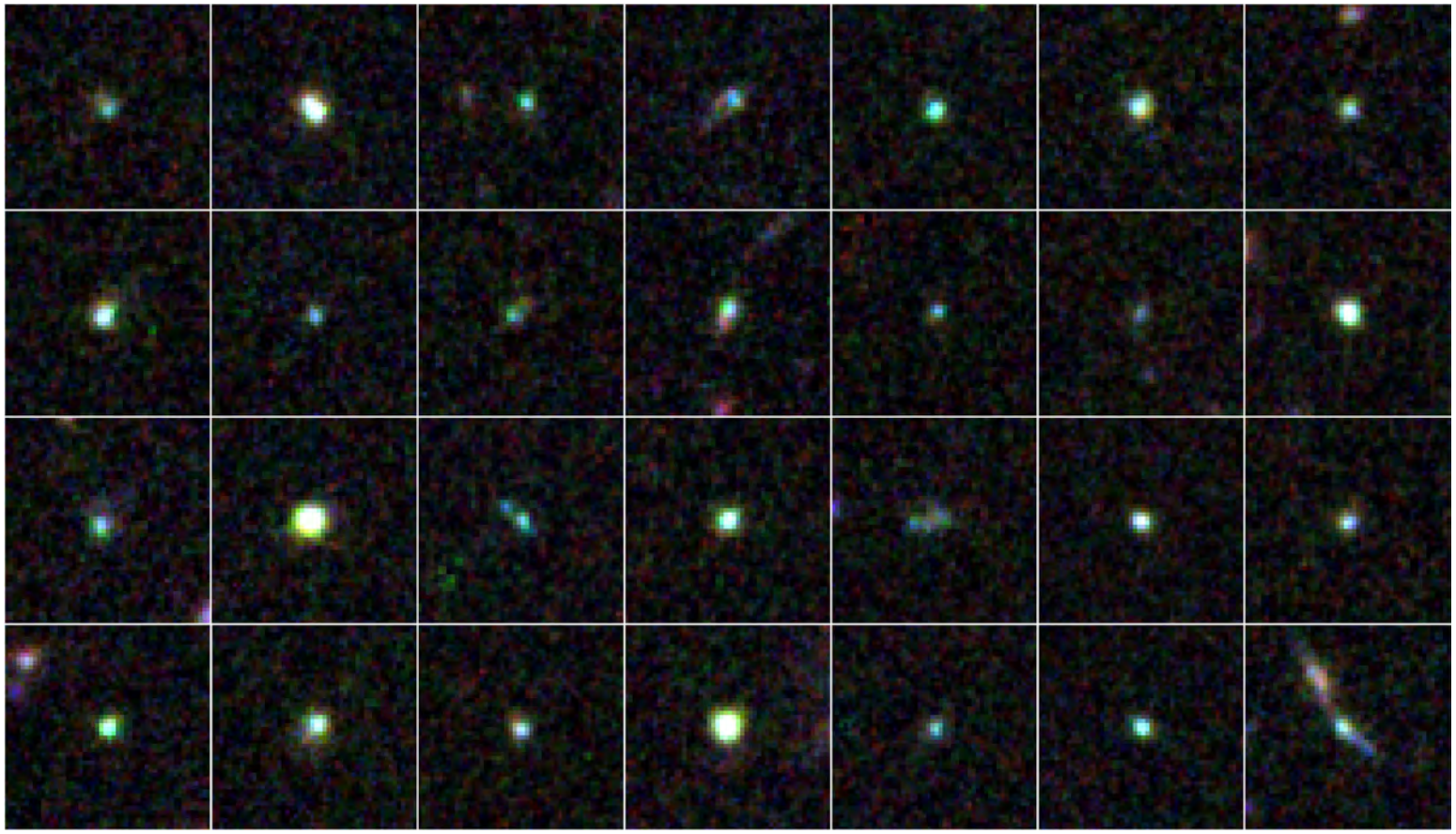
Overview



Extreme emission line galaxies in the Ultra Deep Survey (UDS) by HST

Overview

Characteristics:

- Extremely elevated – 100 to 2000 Å – EWs of emission lines related to SF activity (Hα, $[OIII]_{5007}$, [OII], Ly-α)
- Blue colours & compact morphology
- Among the most metal poor objects in the Universe
- Windows to cosmic history
- Primordial building blocks of local, massive galaxies

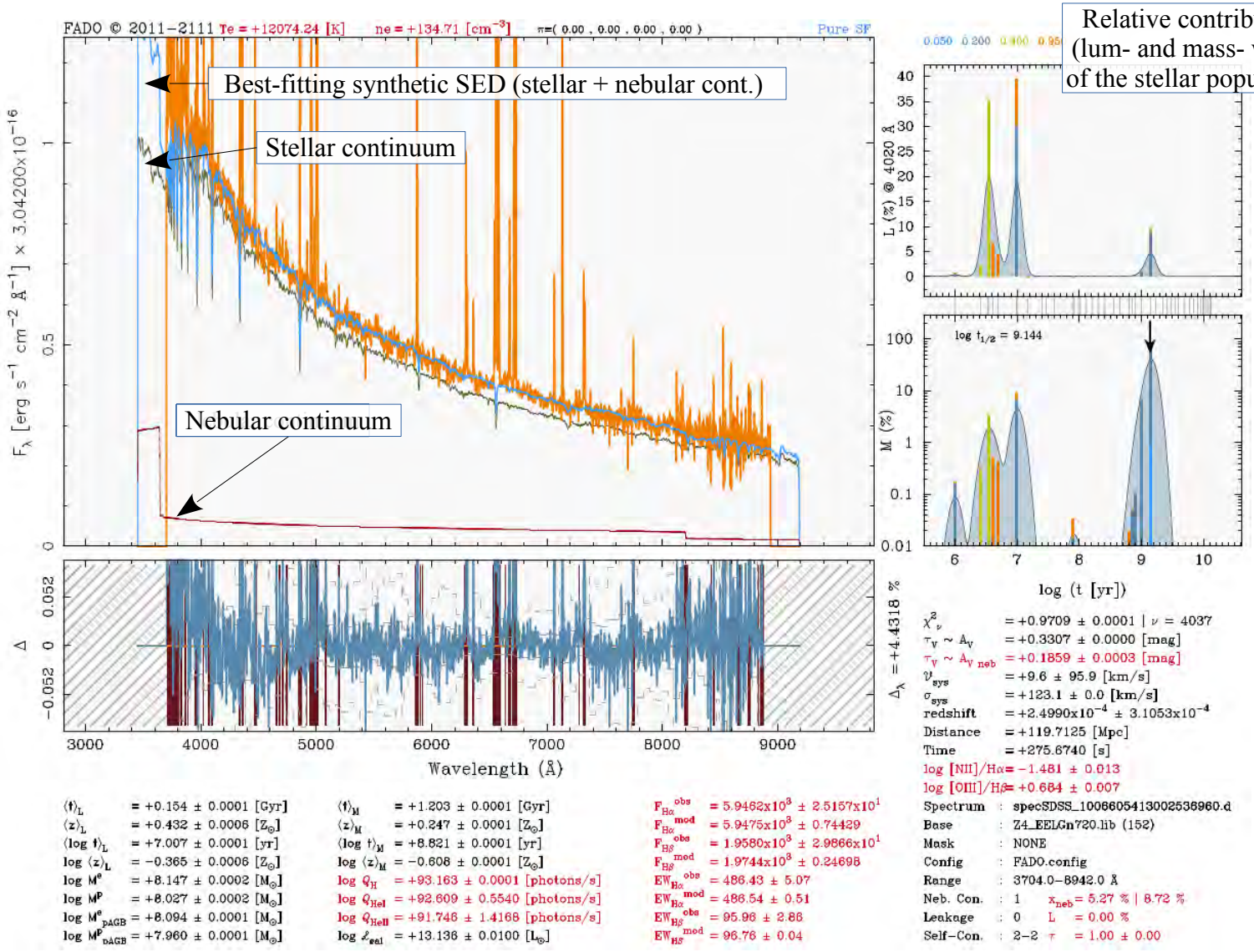
Motivation:

- Important role in the holistic scenario of galaxy evolution
- Elevated nebular emission prevents accurate assessment of stellar content

Aims:

- Characterising the stellar properties of a sample of EELGs (~400 galaxies, ~0.05 < z < ~0.2), by means of self-consistent spectral modelling (FADO, Gomes et al., 2017)
- Comparison with a sample of normal SF galaxies (~700 galaxies)
- Comparison with the standard PSS code *Starlight* ⟶ evaluate the effects of the nebular contamination in a purely stellar code

FADO
(Gomes & Papaderos, 2017; A&A, 603, A63)



- Nebular emission contaminates optical spectra **preventing** the **accurate assessment of the stellar properties**
- FADO is the **only PSS** code that **self-consistently considers the nebular cont.** contribution
  - It **analyses the observed Balmer emission-line lum. & EWs**, thus **constraining** the **nebular continuum shape** (assuming case-B recombination)
  - It then performs spectral synthesis **including the nebular cont.** contribution in the best-fitting SED, while **assessing the combination of SSPs that reproduces best the nebular characteristics** of the galaxy

Identifying the galaxy samples

- **EELG sample:**
  - Main EELG sample of 1969 objects ($0 < z < 0.49$) identified in EPM21 (Pérez-Montero et al., 2021) by applying the ASK classification scheme in SDSS-DR7 data-base (selection criteria – EW(Hβ) > 30Å & EW([OIII]) > 100Å)
  - Rejection of galaxies that do not hold photometric data, critical for aperture corrections
  - Rejection of cometary and tadpole galaxies to which the fibre did not incorporate a significant portion of the galaxy's flux / radial extent
  - Rejection galaxies with low-quality (S/N < 8) SDSS spectroscopic data

  Resulting EELG sample of 464 galaxies

- **Normal SF sample:**
  - Main sample of normal SF galaxies identified via *SDSS DAS User Fiber List Submission Form* (selection criteria – falling below the Kauffmann et al. 2003 line (BPT), minimum S/N of 3 in the most relevant emission lines and within $0.04 \leq z \leq 0.1$)
  - Exclusion of residual and abnormally high SF activity by constraining emission fluxes – $10 \leq EW([OIII]_{5007}) \leq 100$Å, $20 \leq EW(H\alpha) \leq 100$Å and $3 \leq EW(H\beta) \leq 30$Å
  - Random selection of 150 objects within 9 redshift bins
  - Rejection galaxies with low-quality (S/N < 8) SDSS spectroscopic data

  Resulting normal SF sample of 777 galaxies

Spectral modelling

- De-redshift & correct from Galactic extinction the SDSS optical spectra, spline-interpolate to step of 1Å
- Spectral modelling of both samples by means of FADO and *Starlight*
- Complementary runs with $FADO_{ST}$ (purely stellar FADO)
  (entire spectral range was provided to $FADO_{FC}$ while excluding Balmer and Paschen jumps for purely stellar runs)

- Main stellar library comprised of 152 SSP from Bruzual & Charlot (2003), 38 ages between 1 Myr and 13 Gyr & 4 stellar metallicities (0.05, 0.2, 0.4 and 1.0 $Z_{\odot}$)
  (Salpeter initial mass function & Padova 2000 tracks)
- Individual SSP libraries for each galaxy were derived from the main library by removing SSPs which are older than the age of the Universe at the observed *z*

Aperture Corrections

(for the EELG sample only)

- **Emission-derived properties:**
  ◦ Aperture- and extinction-corrected Hα luminosities & SFRs obtained by Duarte-Puertas et al. (2017) prescription

- **Stellar mass:**
  ◦ Stellar mass outside the fibre extrapolated by assuming that the galactic surface brightness profile (μ) of a spectral region free from nebular contamination is a valid proxy to the stellar surface density ($\Sigma_\star$)
- (given their compact and uniform morphology, we work under the reasonably valid assumption that these objects exhibit a constant mass-to-light ratio)
  . After sky modelling & subtraction we extracted from the photometric SDSS frames the μ's in the *g*, *r* and *i* bands
  . To each source, the appointed $\mu \equiv \Sigma_\star$ was selected such that the respective photometric frame is not significantly contaminated by the nebular component – *i* band for $z \leq 0.067$, *r* band for $0.067 < z \leq 0.105$ and *g* band for $z < 0.105$
  ◦ Selected μ's converted to linear units of counts/deg^2, spline interpolated to a constant finer step and integrated within the radius of the fibre ($I_{1.5}$)
  ◦ Division of $I_{1.5}$ by the stellar mass estimated within the fibre results in the factor *f* necessary to convert the total number of counts in the specific filter into total stellar mass
  ◦ Final total stellar mass obtained by integrating the entire previously appointed μ and multiplying by *f*

- In view of their considerable size and heterogeneity aperture corrections of the sample of normal SF galaxies was avoided ⟶ comparison study limited to non-ap.-corrected stellar properties

Spectroscopic analysis

Recovering fundamental correlations between galactic properties

EELGs

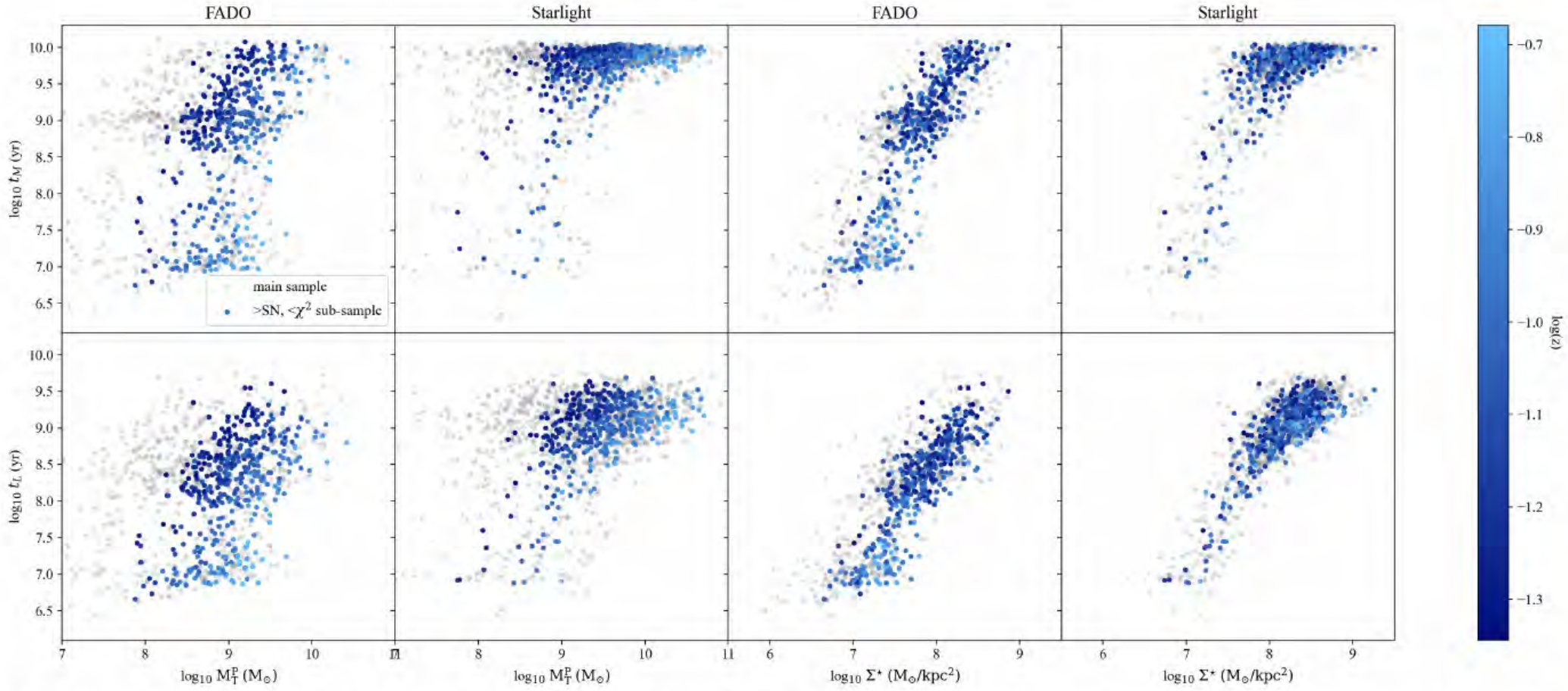
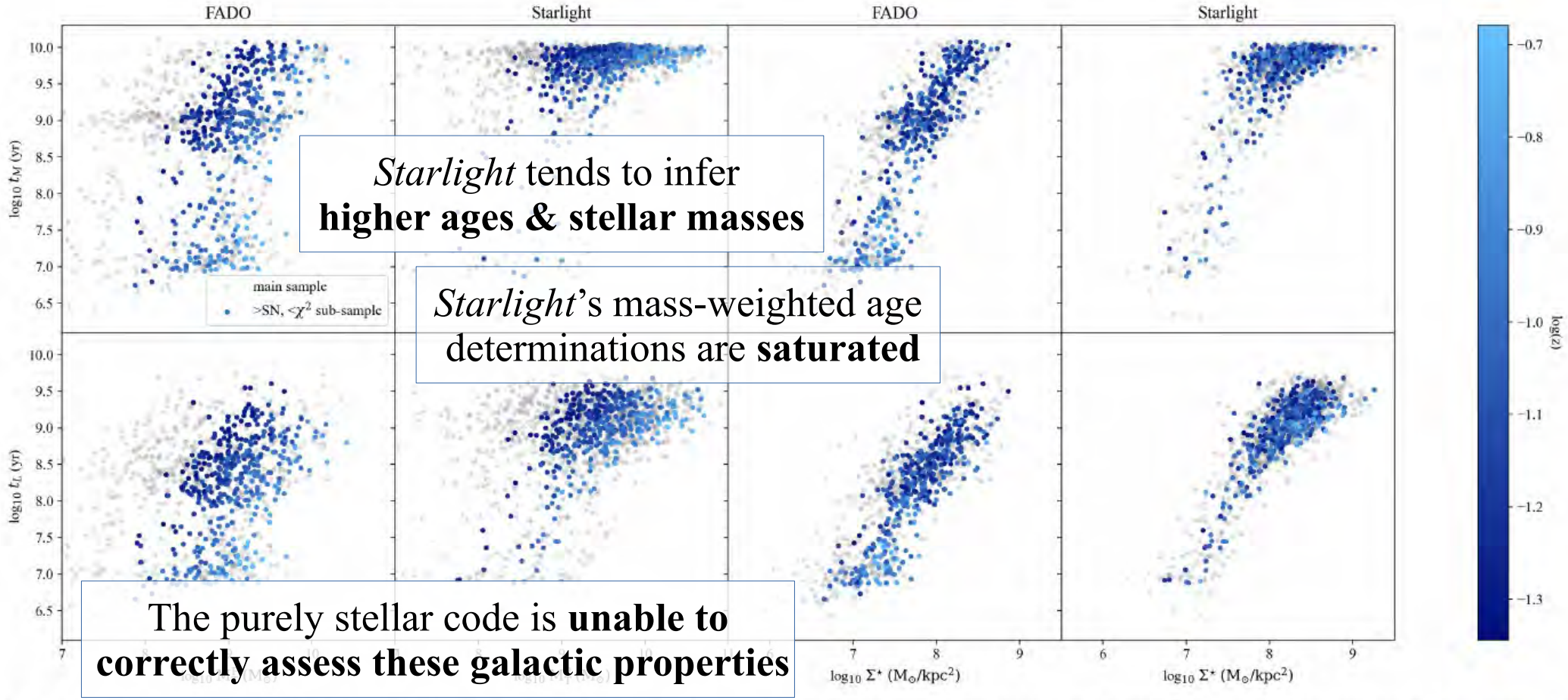


Fig. 6. Correlations between the mean stellar age (mass-weighted in the top row and luminosity-weighted in the bottom row) and the corrected total stellar mass (first four panels) and corrected surface stellar density (last four panels), as obtained by FADO (first and third columns) and STARLIGHT (second and forth columns). Coloured circles depict the high-S/N EELG sample whereas grey circles depict the main EELG sample. The colours correspond to the redshift distribution of the sample, as given by the colour-bar displayed in the right-hand-side of the plot.

Spectroscopic analysis

Recovering fundamental correlations between galactic properties

EELGs



Starlight tends to infer **higher ages & stellar masses**

Starlight's mass-weighted age determinations are **saturated**

The purely stellar code is **unable to correctly assess these galactic properties**

Fig. 6. Correlations between the mean stellar age (mass-weighted in the top row and luminosity-weighted in the bottom row) and the corrected total stellar mass (first four panels) and corrected surface stellar density (last four panels), as obtained by FADO (first and third columns) and STARLIGHT (second and forth columns). Colour-coded [illegible] The colours correspond to the redshift distribution of the sample, as given by the colour-bar displayed in the right-hand-side of the plot.

The FADO analysis reveals **direct correlations between mean stellar age and total stellar mass / stellar surface density**

Spectroscopic analysis

Recovering fundamental correlations between galactic properties

Normal SF

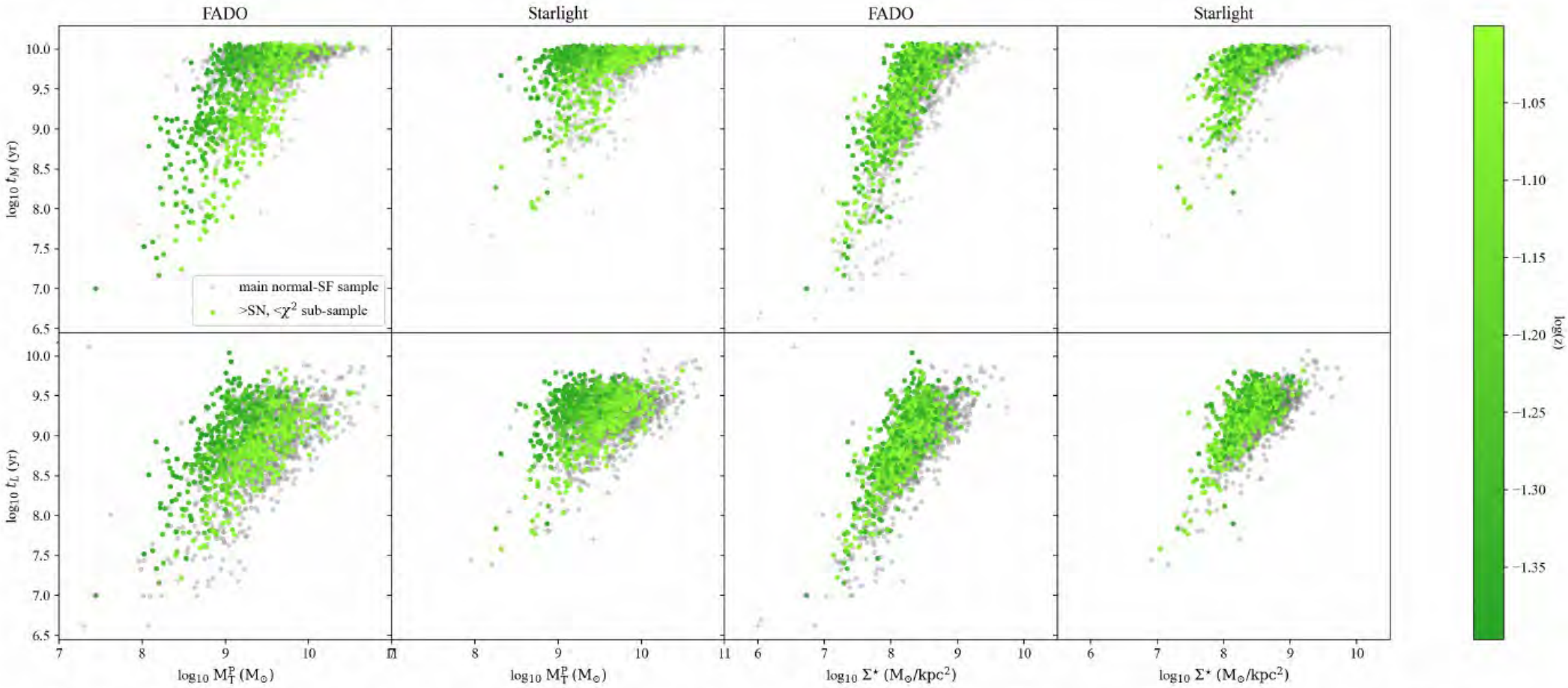
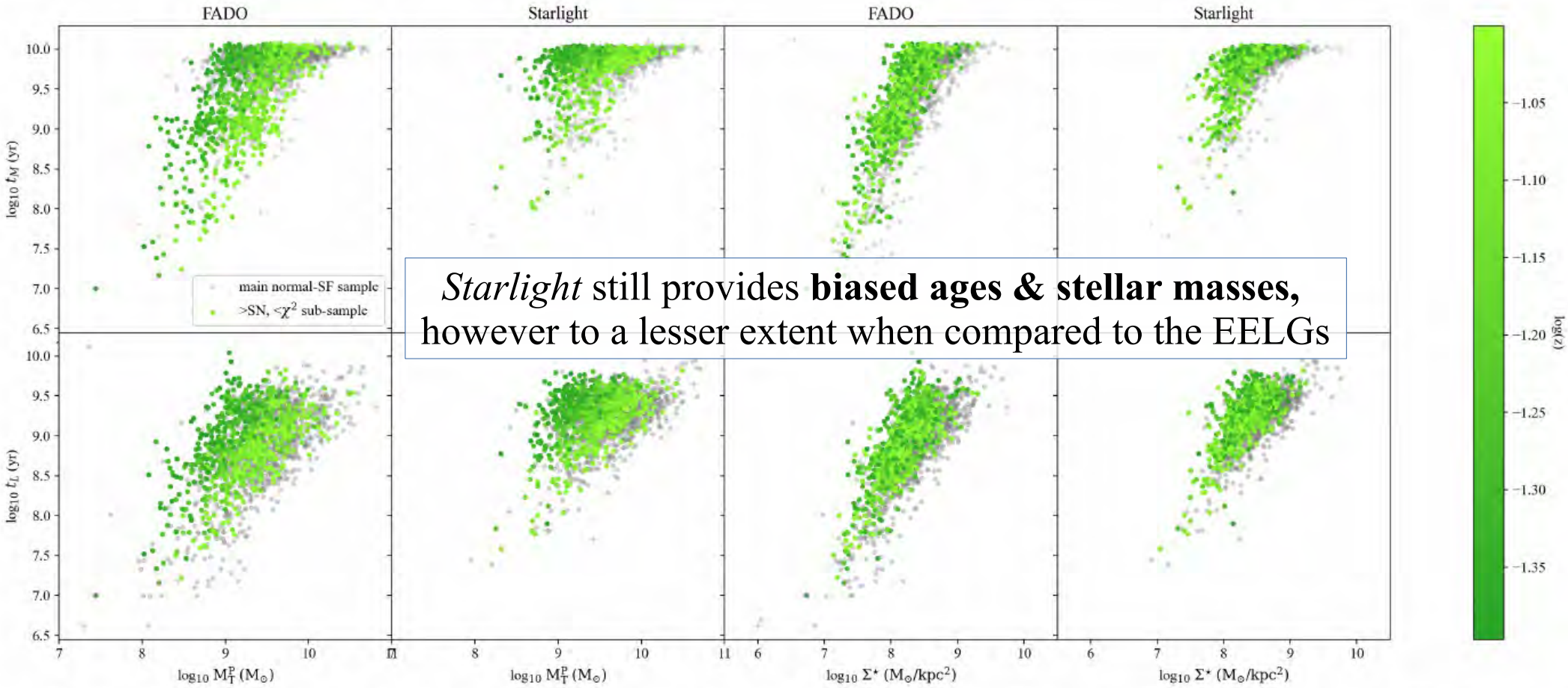


Fig. 7. Repetition of Fig. 6 for the normal SF sample, displaying non-corrected quantities (from aperture effects) for the present-day stellar mass and surface stellar density.

Spectroscopic analysis

Recovering fundamental correlations between galactic properties

Normal SF



Starlight still provides **biased ages & stellar masses,** however to a lesser extent when compared to the EELGs

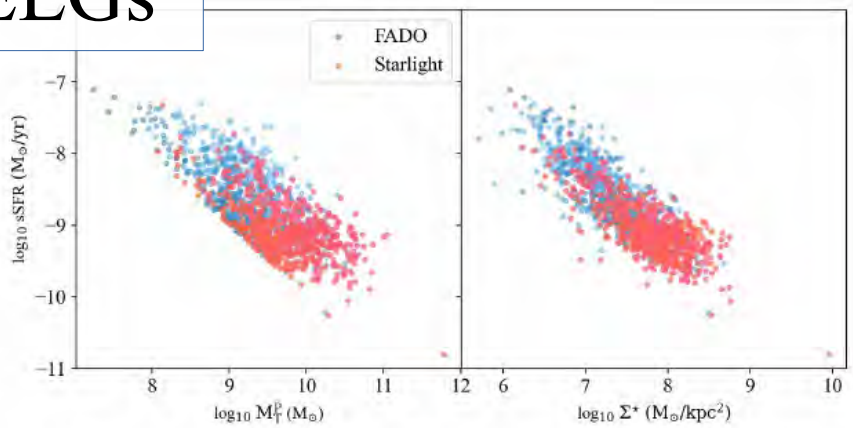
Fig. 7. Repetition of Fig. 6 for the normal SF sample, displaying non-corrected quantities (from aperture effects) for the present-day stellar mass and surface stellar density.

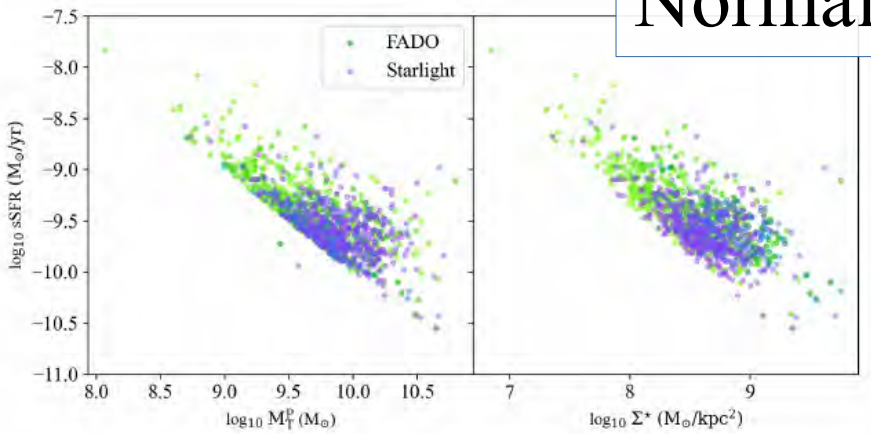
Spectroscopic analysis

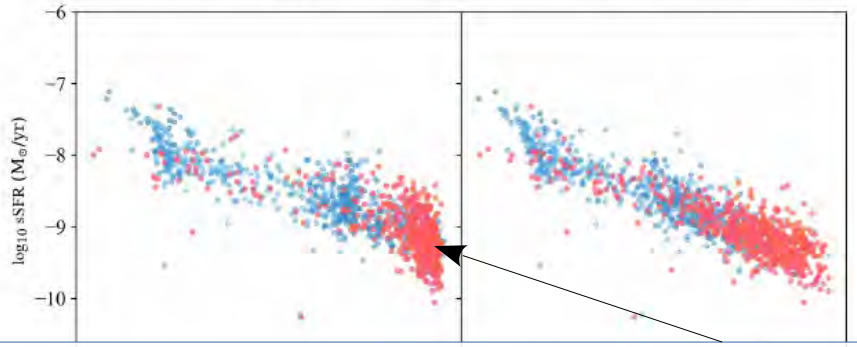
Recovering fundamental correlations between galactic properties

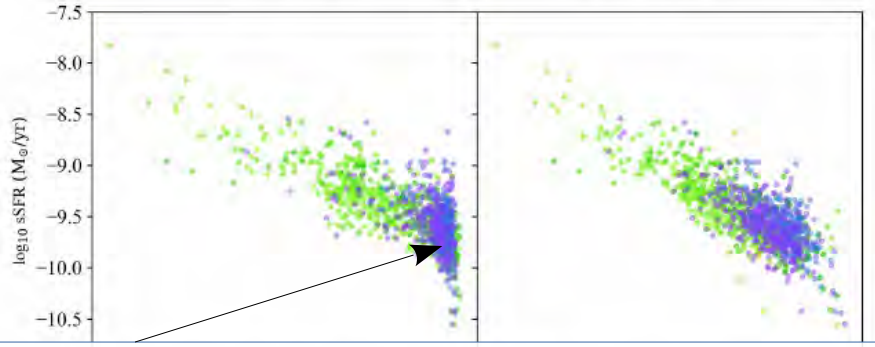
EELGs

Normal SF









Artificial saturation driven by the nebular emission, unaccounted in purely stellar runs

Fig. 8. On the top row it is displayed the logarithm of the aperture corrected sSRF versus the aperture-corrected stellar mass (left panel) and the aperture-corrected $\Sigma_\star$(right panel). The bottom row displays the logarithm of the aperture-corrected sSFR versus the mass-weighted mean stellar age (left panel), followed by the same versus the luminosity-weighted mean stellar age (right panel).

Fig. 9. Equivalent to Fig. 8 but for the normal SF galaxy sample. Contrary to the EELG sample, stellar mass and surface density estimates are not corrected from aperture effects.

Spectroscopic analysis

Inspecting the factors impacting the determination of the stellar properties

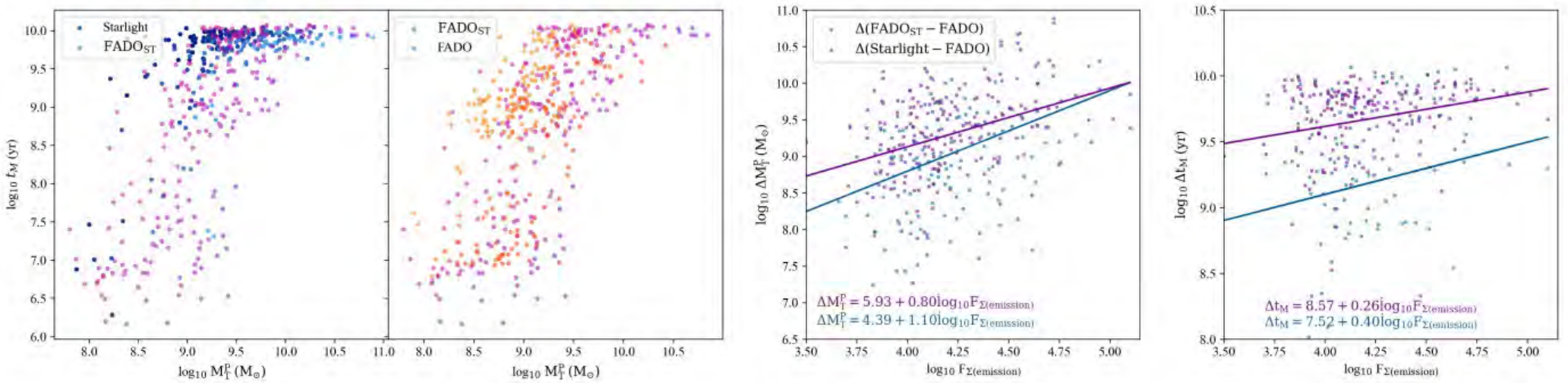


Fig. 10. Mass-weighted mean stellar age distribution with present-day stellar mass, as obtained by STARLIGHT, FADO and FADO$_{ST}$. The left-hand side panel compares the aforementioned distribution as obtained by STARLIGHT and FADO$_{ST}$, whereas the middle panel compares the same as obtained for FADO and FADO$_{ST}$. The two right-hand side panels demonstrate how the normalised difference between the estimated stellar mass and mass-weighted stellar age (considering and ignoring the nebular contribution) relates to the logarithm of the flux associated with the sum of all emission lines, $\log_{10} F_{\Sigma(emission)}$, in units of 10^{-16} erg/cm^2.s, which is a direct proxy for the nebular continuum level. Linear regressions to the respective data points are overlaid.

The differences between the stellar properties obtained by purely stellar (*Starlight* and FADO$_{ST}$) and FADO$_{FC}$ can be correlated with the intensity of the nebular emission

Comparative analysis

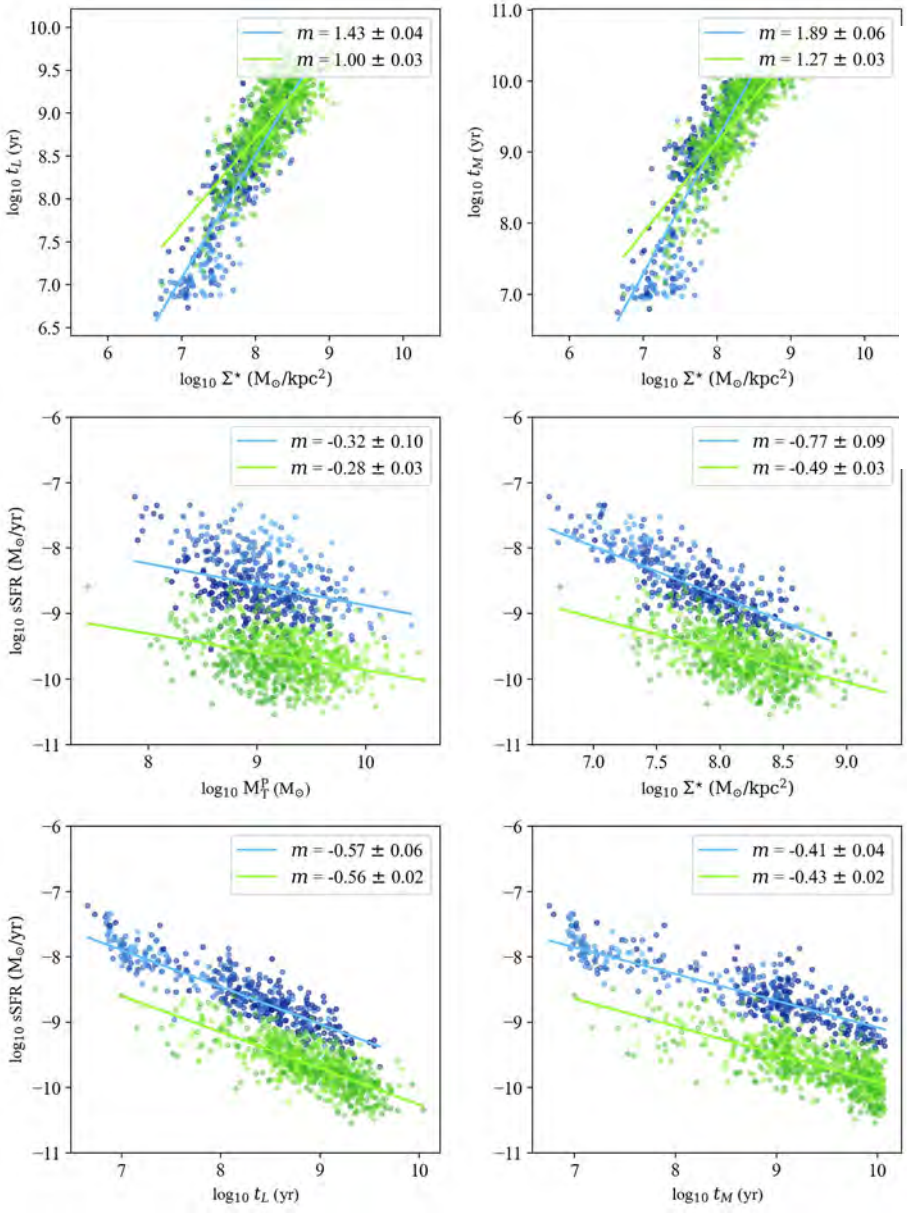


Fig. 13. Comparison of fundamental relations as obtained for EELGs (blue) and normal SF galaxies (green). The top row displays the correlations between mean stellar age (luminosity-weighted at the left-hand side and mass-weighted at the right-hand-side) and stellar surface density. The middle row contains, at the left-hand side, the relation between present day stellar mass and the logarithm of the sSFR and at the right-hand side, stellar surface density versus the logarithm of the sSFR. The left-hand side (right-hand side) of the bottom row displays the relations between the luminosity-weighted (mass-weighted) mean stellar age and the logarithm of the sSFR. The legends display the values of the slopes after performing linear fits to the respective data points and respective standard deviations

EELGs vs. normal SF gal.:

◦ EELGs and normal SF galaxies show equivalent mean stellar ages for the same $\Sigma_{\star}$

◦ EELGs occupy a wider (lower) region of the $\Sigma_{\star}$ vs $t_{\star}$ par. space

◦ EELGs yield considerably higher values of sSFR for the same stellar mass

Possible explanations:

i) Pronounced underlying old stellar component – despite the high values of sSFR, the contribution of the young stellar component is much lower than the same of the old

ii) Significantly different SFHs – normal SF galaxies display more continuous SFHs, in contrast to EELGs which suddenly endure violent but brief star-formation episode(s)


THANKS!!
OBRIGADA!!
GRACIAS!!