

Simulations versus observations: toward a consistent comparison

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G. Guidi, CS, C.J. Walcher, 2015, MNRAS, 454, 2381

G. Guidi, CS, C.J. Walcher, A. Gallazzi, submitted (astro-ph/1602.06297)

Simulations versus observations

- How well do simulated galaxies agree with observational results?

The methods we use to calculate the properties of simulated galaxies are very different to those used in observations, and the comparisons are in general not reliable.

- What can we do to know how realistic simulated galaxies are?

Ask a simulator...

who made the simulations and knows all about the galaxy

Or

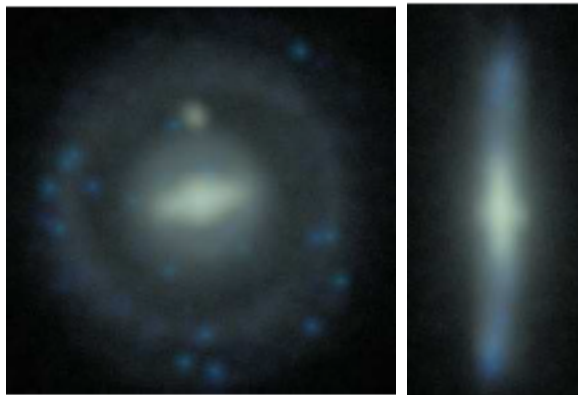
Ask an observer...

who knows how to extract galaxy properties from an observation

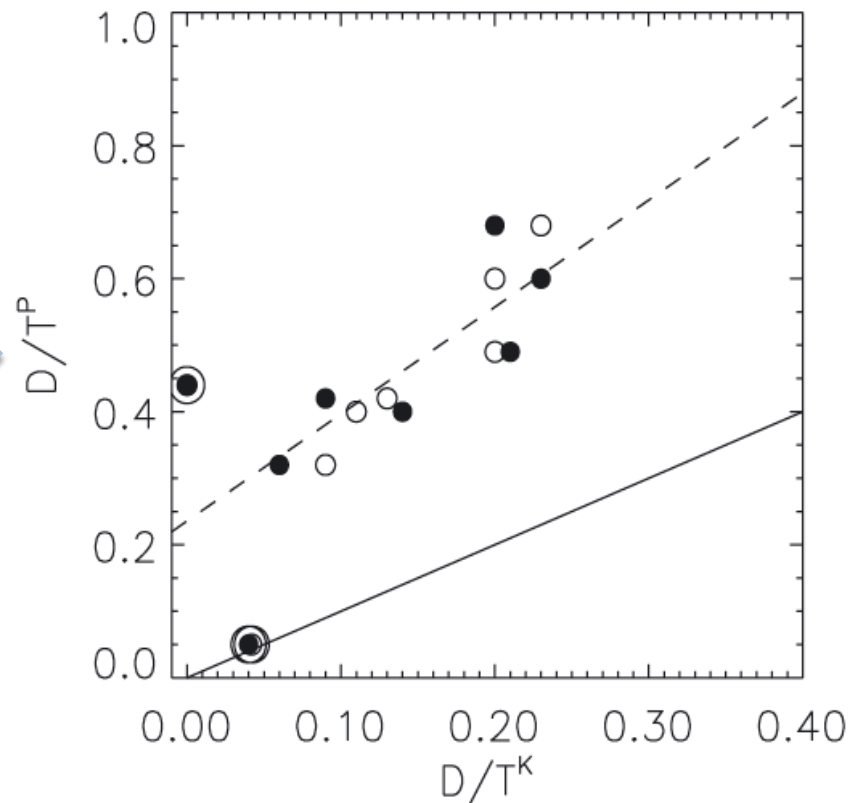
- And you will get a different answer!

Simulations versus observations

Kinematic decomposition vs
disk-bulge-bar decomposition



Observer



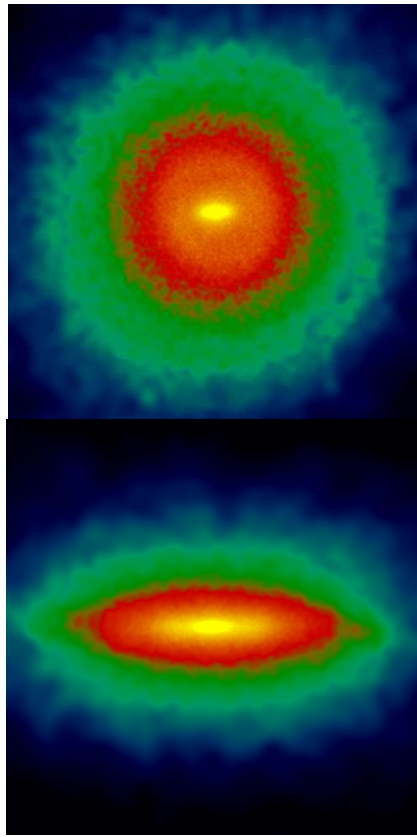
Simulator

The observer sees a disk-dominated galaxy...

But I see a bulge-dominated galaxy!!!!

Simulations versus observations

- How well do simulated galaxies agree with observational results?
- Can we properly quantify the (dis)agreement between simulated and observed galaxies?



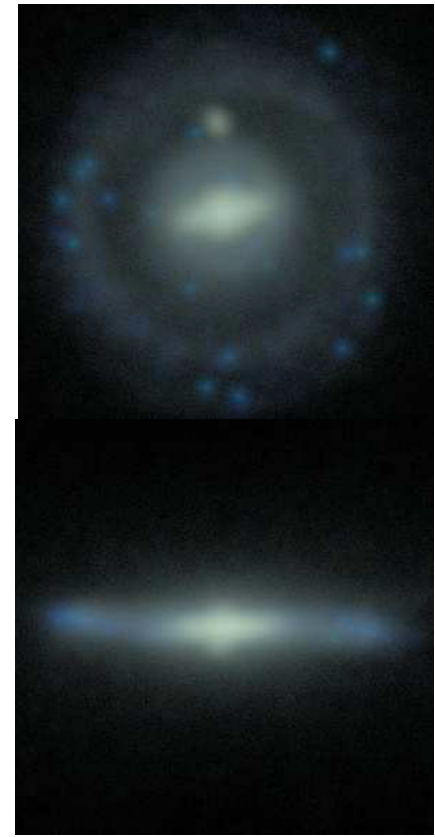
Need to create a synthetic
observation



a) SPS models (eg BC03)

b) SPS models + dust

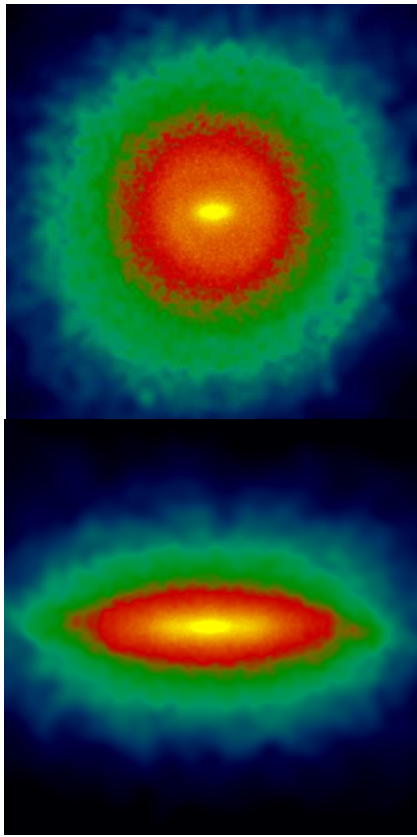
c) Radiative transfer
(SUNRISE code,
Jonsson 2006)



Simulations versus observations

Study how different the observationally-derived quantities are from the *real* ones (direct result of the simulation).

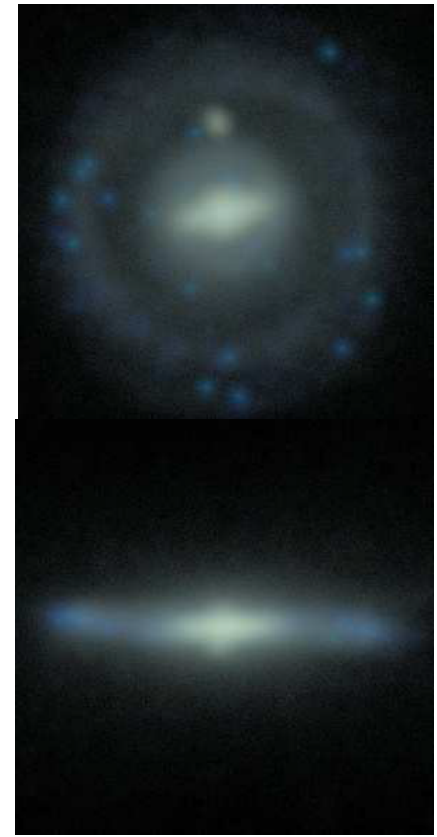
Look for systematic biases in the derivation of galaxy properties.



Need to create a synthetic
observation

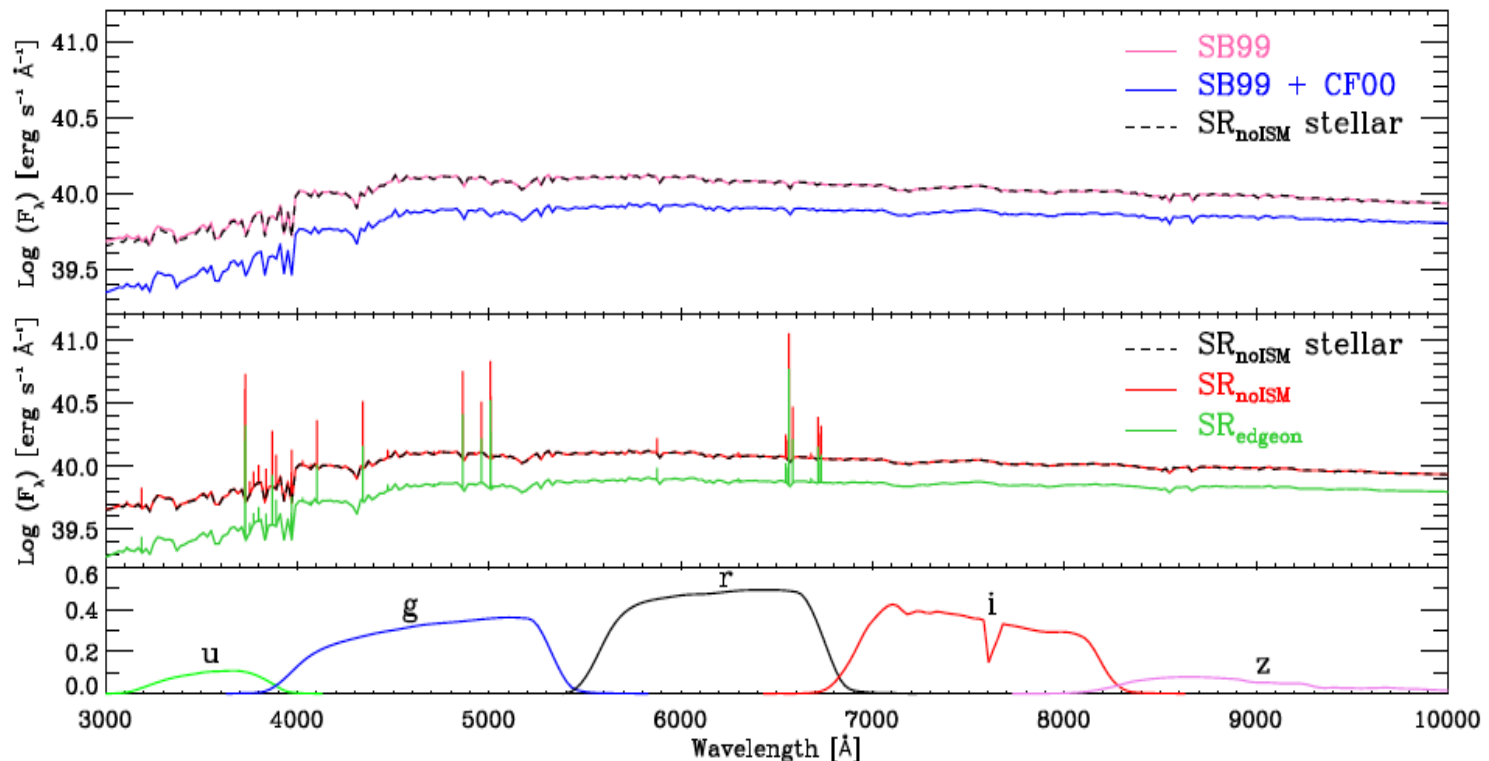


Apply the **same**
techniques used in
(given)
observations



Simulations versus observations

- SPS and radiative transfer (RT) codes also give spectra, which is the main source of information of large galaxy surveys (e.g. SDSS)



The simulated galaxy sample

- 5 Aquarius galaxies: AqA to AqE
- Simulated with 3 different versions of GADGET3:
 - “CS” Scannapieco et al. (2005, 2006)
 - “CS+” Poulhazan et al. (in prep), CS with updates to chemical model
 - “MA” Aumer et al. (2013), CS with updated to chemical model and feedback, including radiation pressure

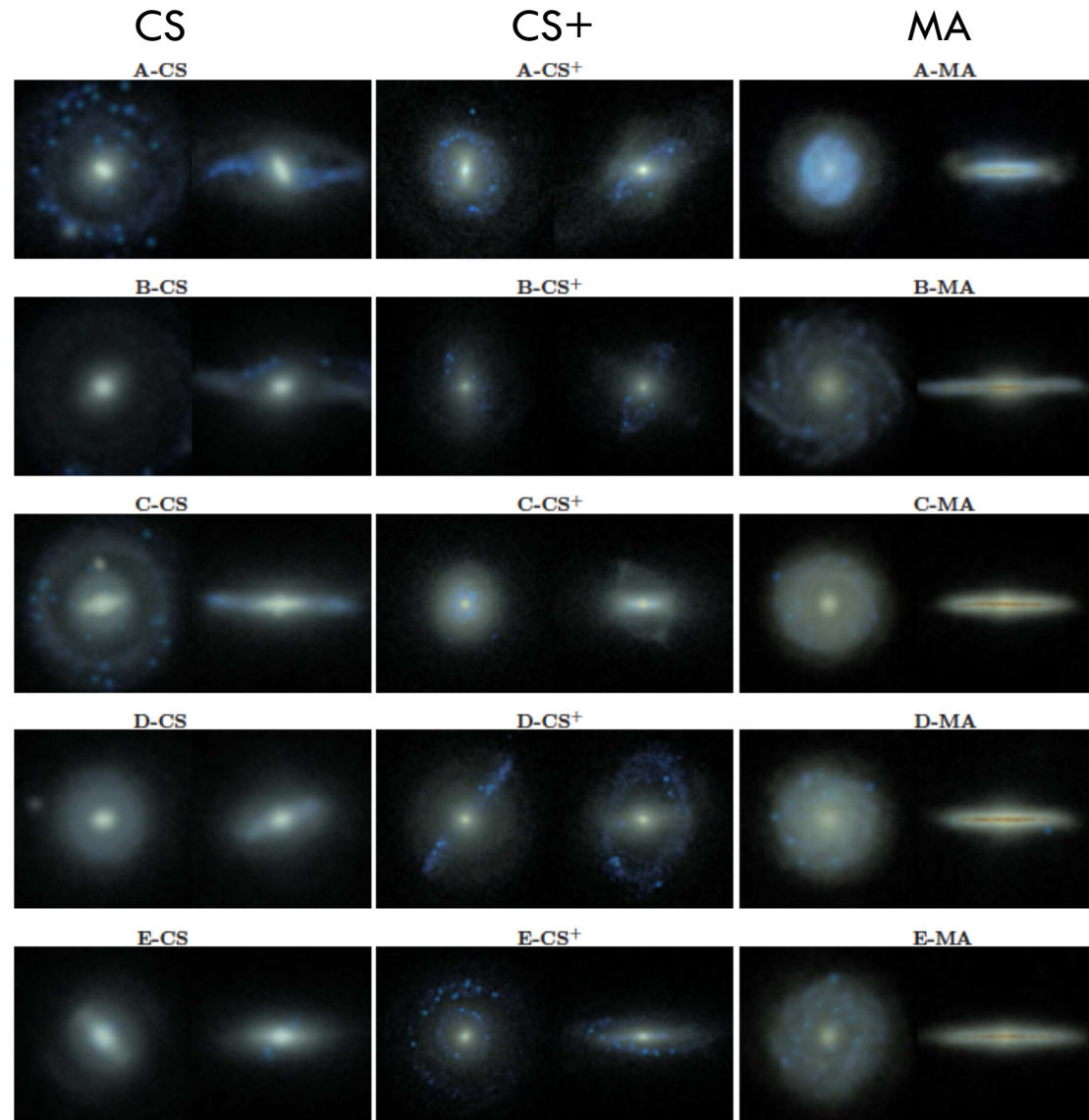
The simulated galaxies

CS to MA:

more disk

more extended

younger stellar populations



Creating the synthetic observations

- Models also have assumptions/input parameters
- SPS models:
 - Bruzual & Charlot 2003
 - STARBURST99 – Leitherer et al. 1999
 - PEGASE – Fioc & Rocca-Volmerange 1997,1999
 - FSPS – Conroy et al. 2009
 - Maraston 2005
- DUST:
 - Charlot & Fall 2000
 - Other extinction curves
- SUNRISE:
 - Statistically sample processes of photon emission, scattering and absorption
 - SUNRISE includes nebular and stellar spectrum (MAPPINGSIII)
 - Can have all orientations, we compute face-on and edge-on images/spectra
 - Input paramters, e.g.
 - Constant dust-to-metals mass ratio (we assume 0.4, Dwek 1998)

Mimicking observations

- Biases depend on the characteristics of the observing strategies.
- Focus on the Sloan Digital Sky Survey (SDSS):
 - will use 5 SDSS photometric bands and mimic SDSS techniques to get galaxy properties (magnitudes, colors, **stellar/gas metallicities, stellar ages**, star formation rates, **stellar masses**)
 - will test effects of fiber bias that affects SDSS spectrograph
 - will compare direct results of simulations (SIM method) to those obtained following observational techniques (OBS method).
 - will try to find easy-to-calculate quantities from the simulations that can be easily compared to observations without the need to generate the synthetic images/spectra

Mimicking SDSS: fiber bias

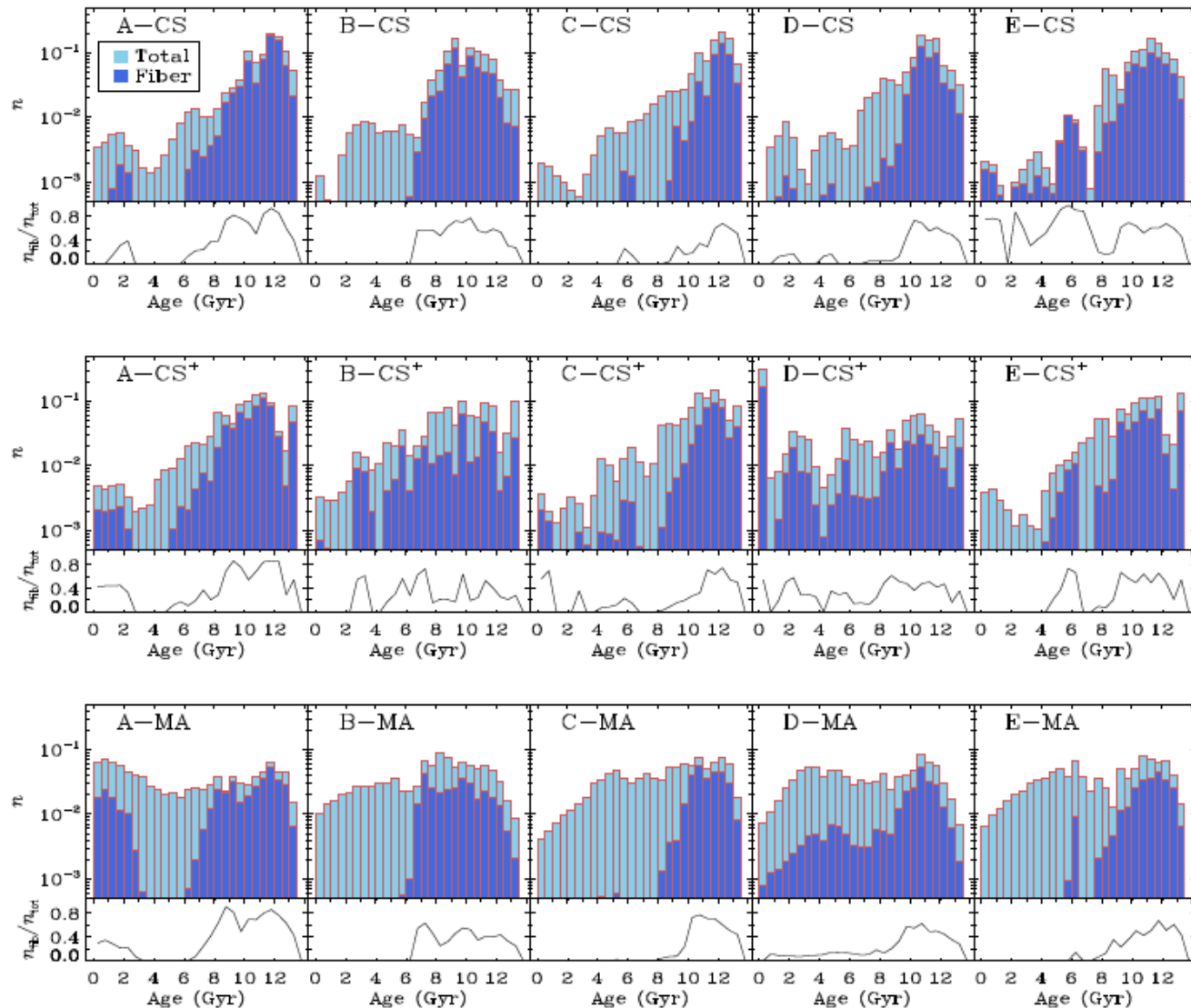
Age

(we use $r_{\text{fib}} = 4\text{kpc}$)

Fiber quantities
preferentially sample
the older stellar
populations.

Sampling functions
typically higher than
50%.

Dependence with age
profile.



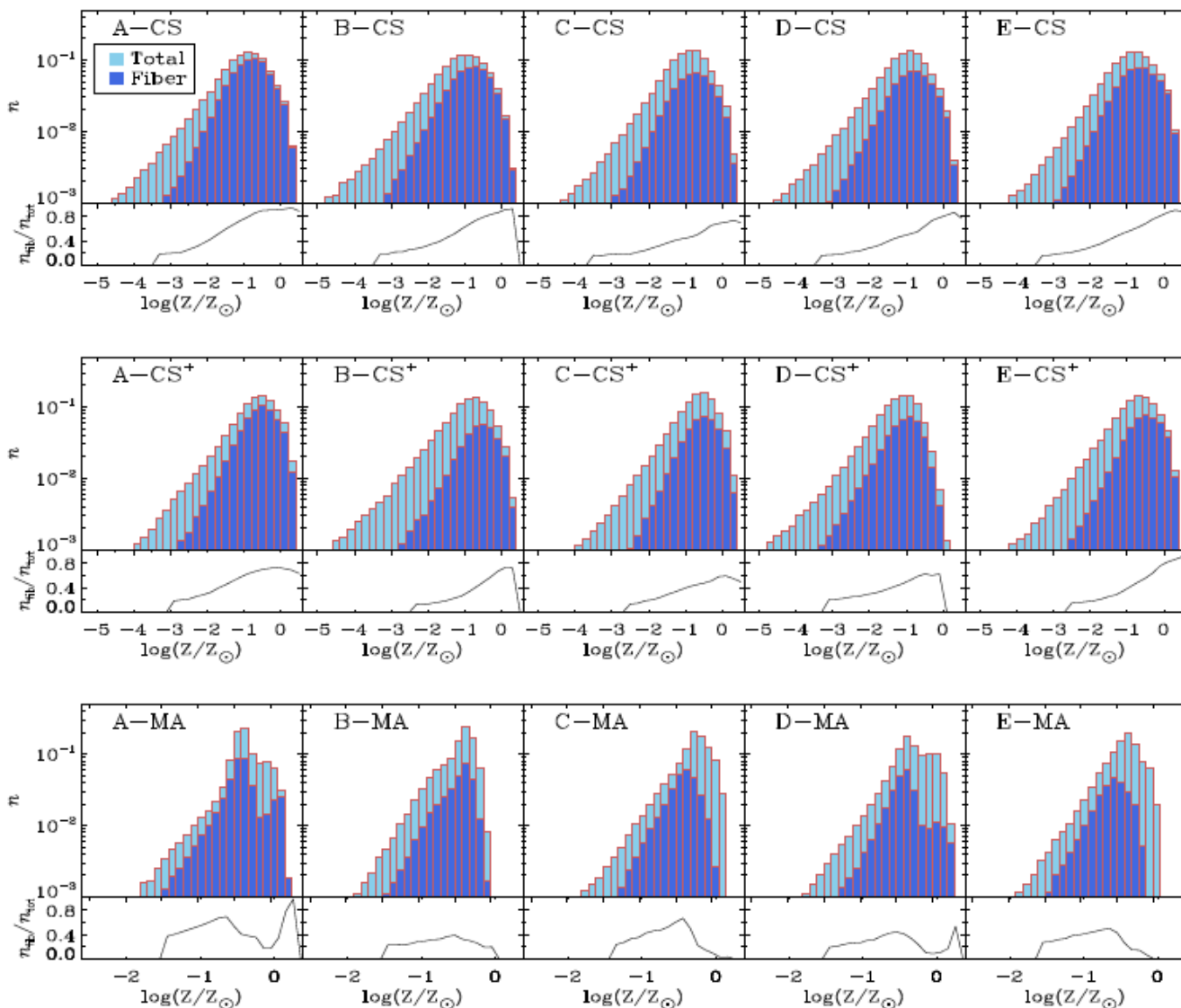
Mimicking SDSS: fiber bias

Stellar metallicity

Preferential sample of metal-rich populations.

Sampling functions similar for the different galaxies.

Dependence with metallicity profile (CS galaxies have stronger metallicity profiles compared to MA).



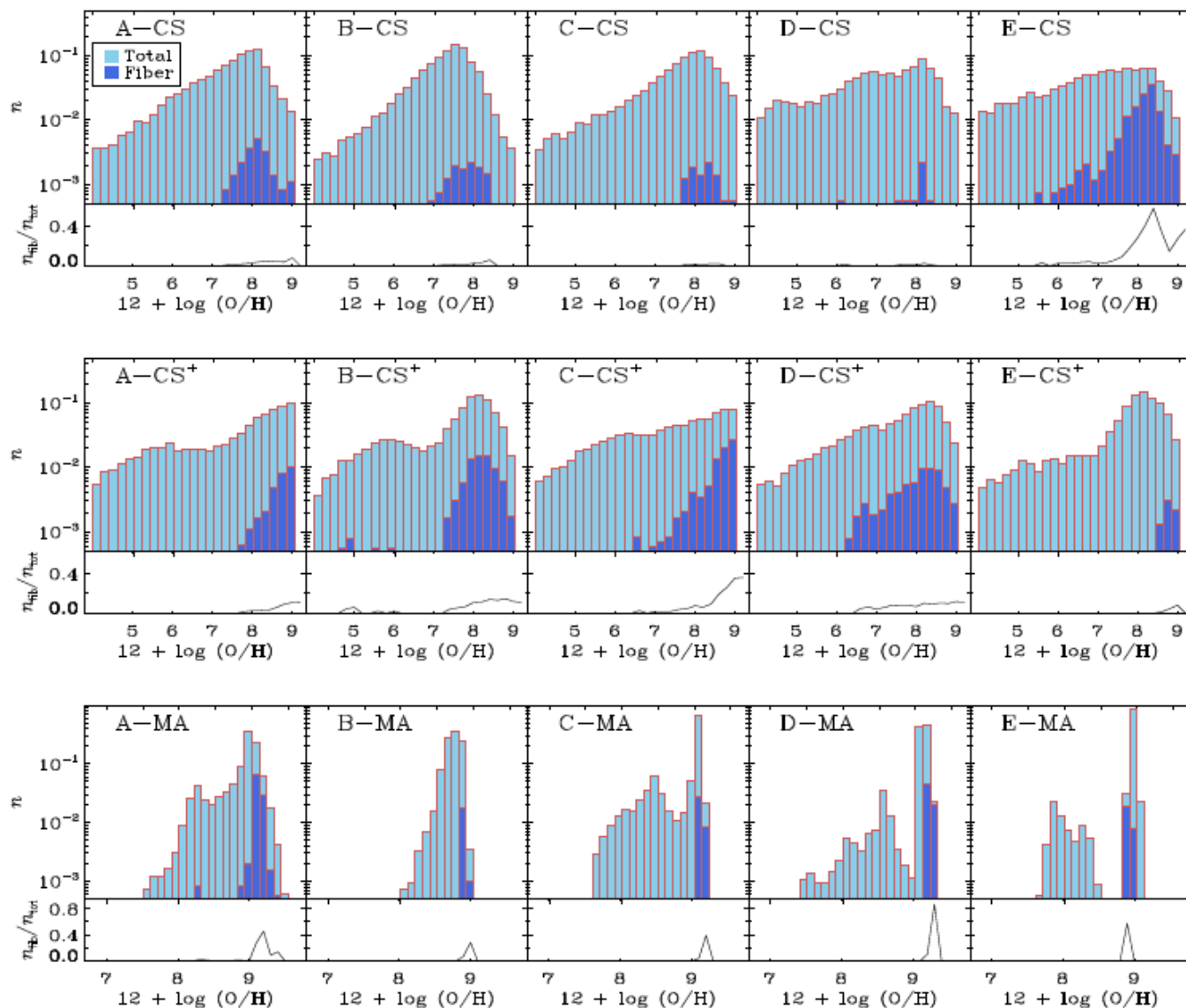
Mimicking SDSS: fiber bias

Gas metallicity

Preferential sample of metal-rich populations.

Very poor sampling, particularly at low metallicities.

Different samplings for different galaxies, depending on the metallicity profile



Results I: Stellar masses

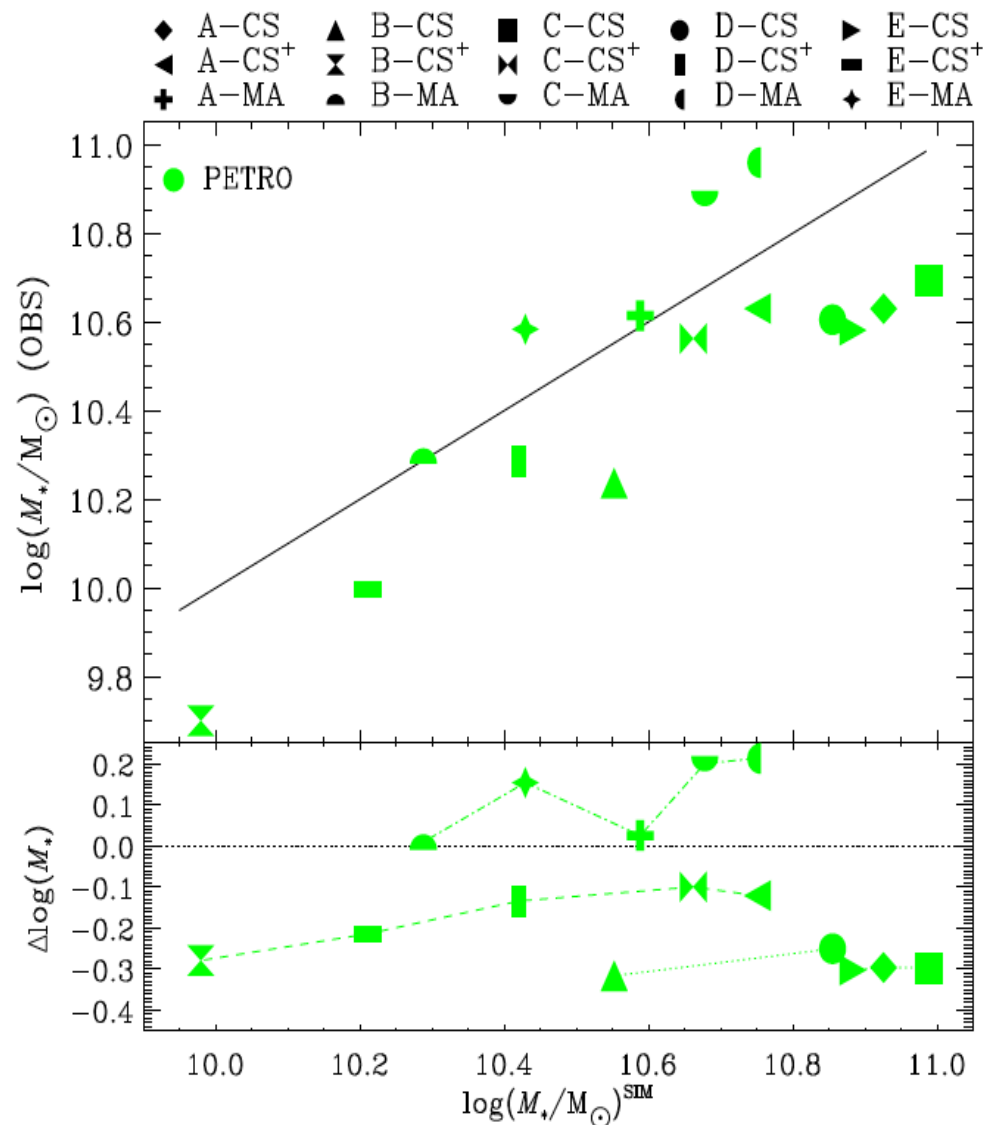
SIM: $M_* = \sum m_i$

PETRO (OBS):

fit of Petrosian magnitudes (u, g, r, i, z , after subtracting nebular emission) to grid of models of Walcher et al. (2008).

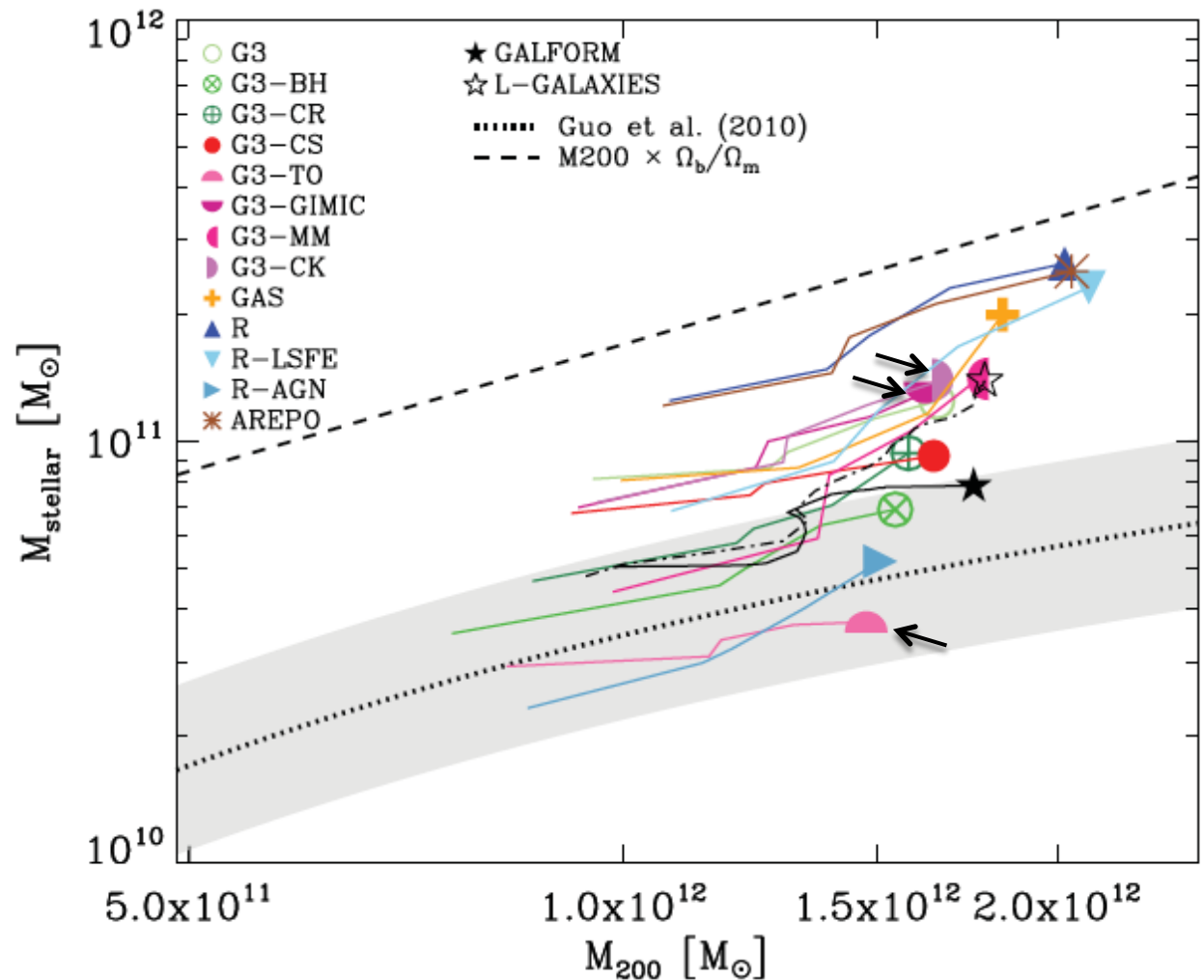
($M(r < 2r_{\text{pet}}) > 85\%$)

- Models that consider stellar mass loss by AGB stars, better recover the real stellar mass.
- Differences between M_*^{SIM} and M_{OBS}^* can be large.



Halo-to-stellar mass: Aquila Project

Only
G3-TO,
G3-GIMIC and
G3-CK
included AGB!



Results II: Stellar ages

SIM: $\text{Age} = \sum (m_i A_i) / \sum m_i$

SIM-LUM-fiber:

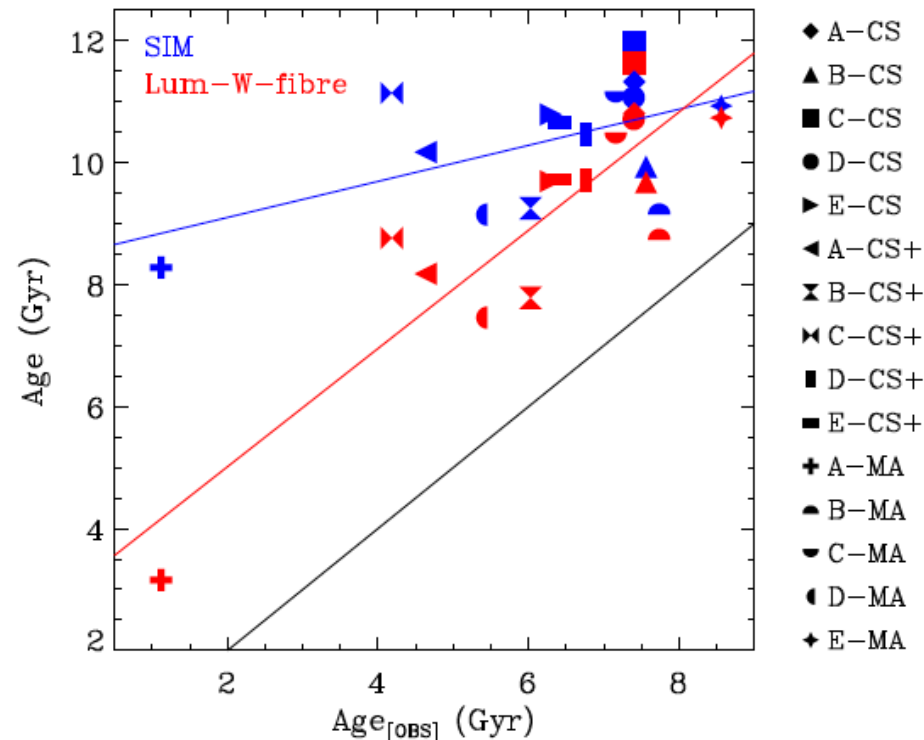
$$\text{Age} = \sum (I_i A_i) / \sum I_i \quad (i: \text{part. within fiber})$$

LICK-IND-fiber (OBS):

fit of Lick indices, Gallazzi et al. 2005

□ No strong correlation between SIM and OBS methods

□ SIM-LUM-fiber decreases the scatter and gives higher R



$$\text{Age}_{[\text{SIM}]} = 0.30 \times \text{Age}_{[\text{OBS}]} + 8.51$$

$$R_{[\text{SIM}]} = 0.545$$

$$\text{Age}_{[\text{Lum-W-fibre}]} = 0.97 \times \text{Age}_{[\text{OBS}]} + 3.07$$

$$R_{[\text{Lum-W-fibre}]} = 0.881$$

Results III: Stellar metallicities

SIM: $Z = \sum (m_i Z_i) / \sum m_i$

SIM-LUM-fiber:

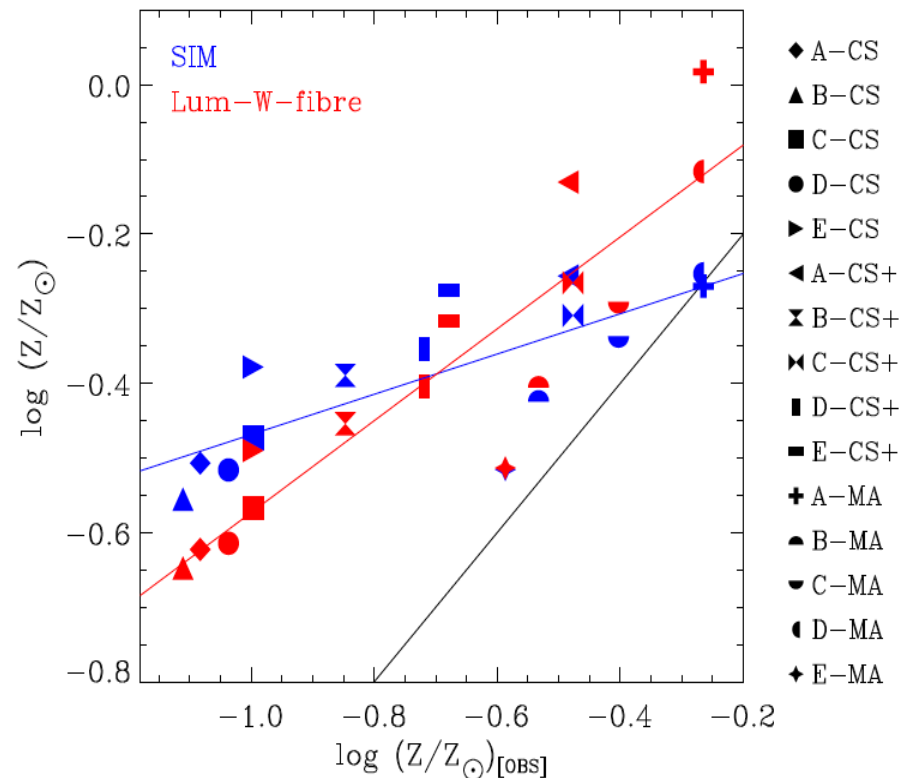
$$Z = \sum (I_i Z_i) / \sum I_i \quad (i: \text{part. within fiber})$$

LICK-IND-fiber (OBS):

fit of Lick indices, Gallazzi et al. 2005

- Good correlation between SIM and OBS methods

- SIM-LUM-fiber decreases the scatter and gives higher R



$$\log(Z/Z_{\odot})_{\text{SIM}} = 0.270 \times \log(Z/Z_{\odot})_{\text{OBS}} - 0.199$$

$$R_{\text{SIM}} = 0.759$$

$$\log(Z/Z_{\odot})_{\text{Lum-W-fibre}} = 0.616 \times \log(Z/Z_{\odot})_{\text{OBS}} - 0.042$$

$$R_{\text{Lum-W-fibre}} = 0.903$$

Results IV: Gas metallicities

SIM: $Z_{\text{gas}} = \sum (m_i Z_{i,\text{gas}}) / \sum m_i$
(Z is now oxygen abundance)

SIM-fiber:

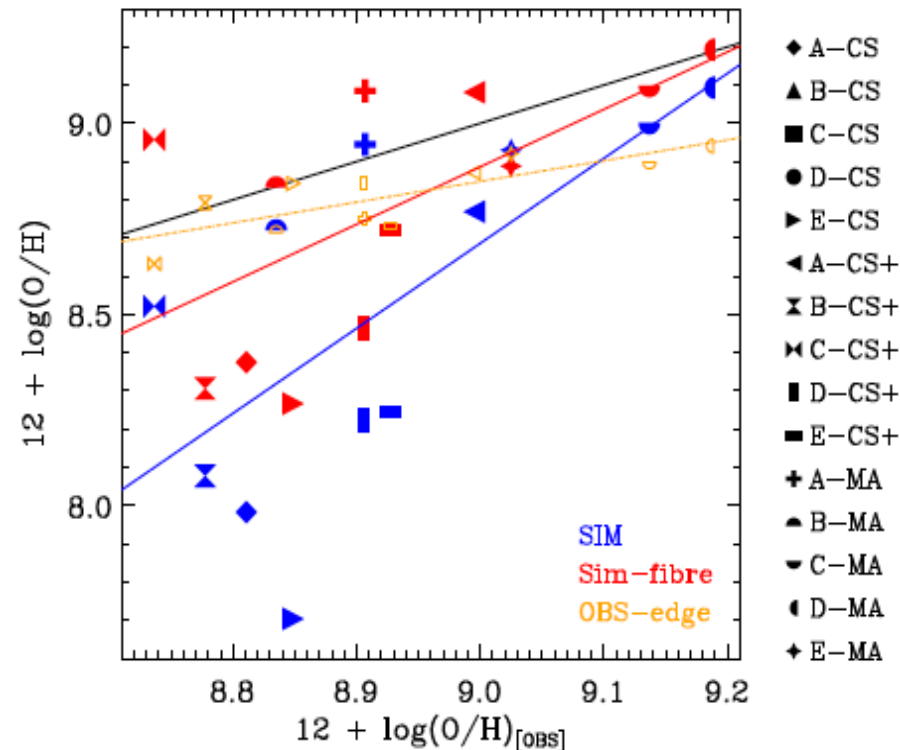
$$Z_{\text{gas}} = \sum (m_i Z_{i,\text{gas}}) / \sum m_i \quad (i: \text{part. within fiber})$$

T04-fiber (OBS):

apply the SDSS Tremonti et al. calibration (valid on upper branch of the R23-metallicity relation) to face-on/edge-on spectra

□ Similar R for SIM and SIM-fiber methods

□ Offset between SIM and OBS methods lower for the higher abundances



$$12 + \log(O/H)_{[SIM]} = 2.22 \times \{12 + \log(O/H)_{[OBS]}\} - 11.33$$

$$R_{[SIM]} = 0.674$$

$$12 + \log(O/H)_{[Sim-fibre]} = 1.50 \times \{12 + \log(O/H)_{[OBS]}\} - 4.65$$

$$R_{[Sim-fibre]} = 0.621$$

What about other methods?



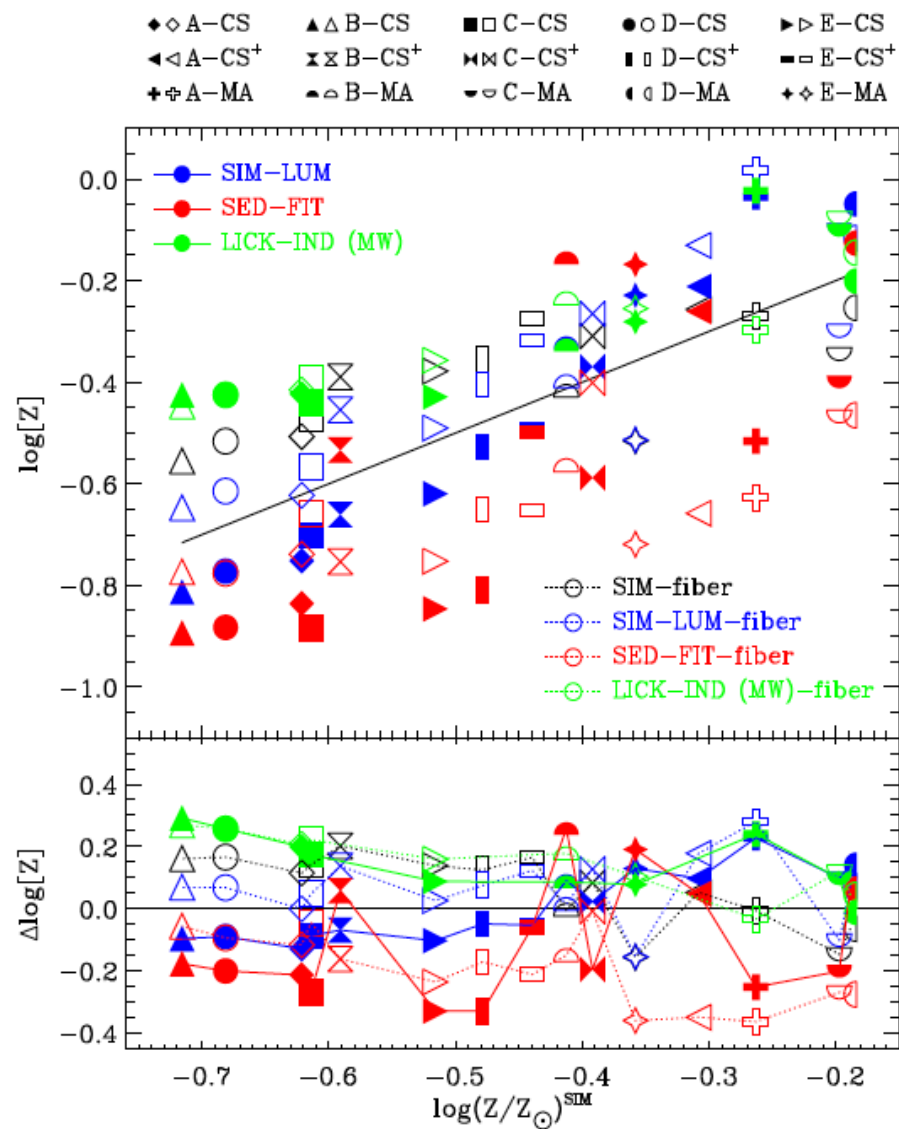
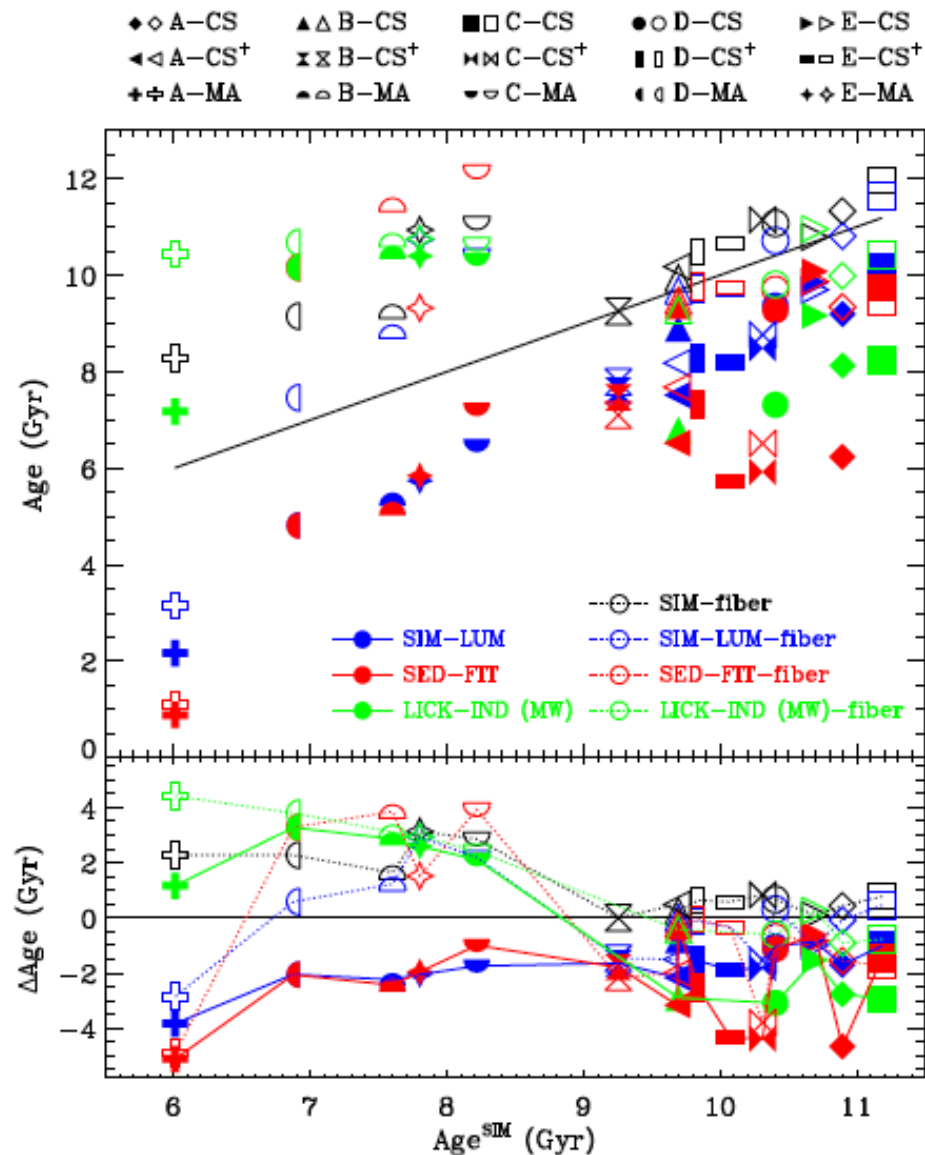
We have tried various different methods that are usually done by simulators to do comparisons with observations

... and ... of course ...

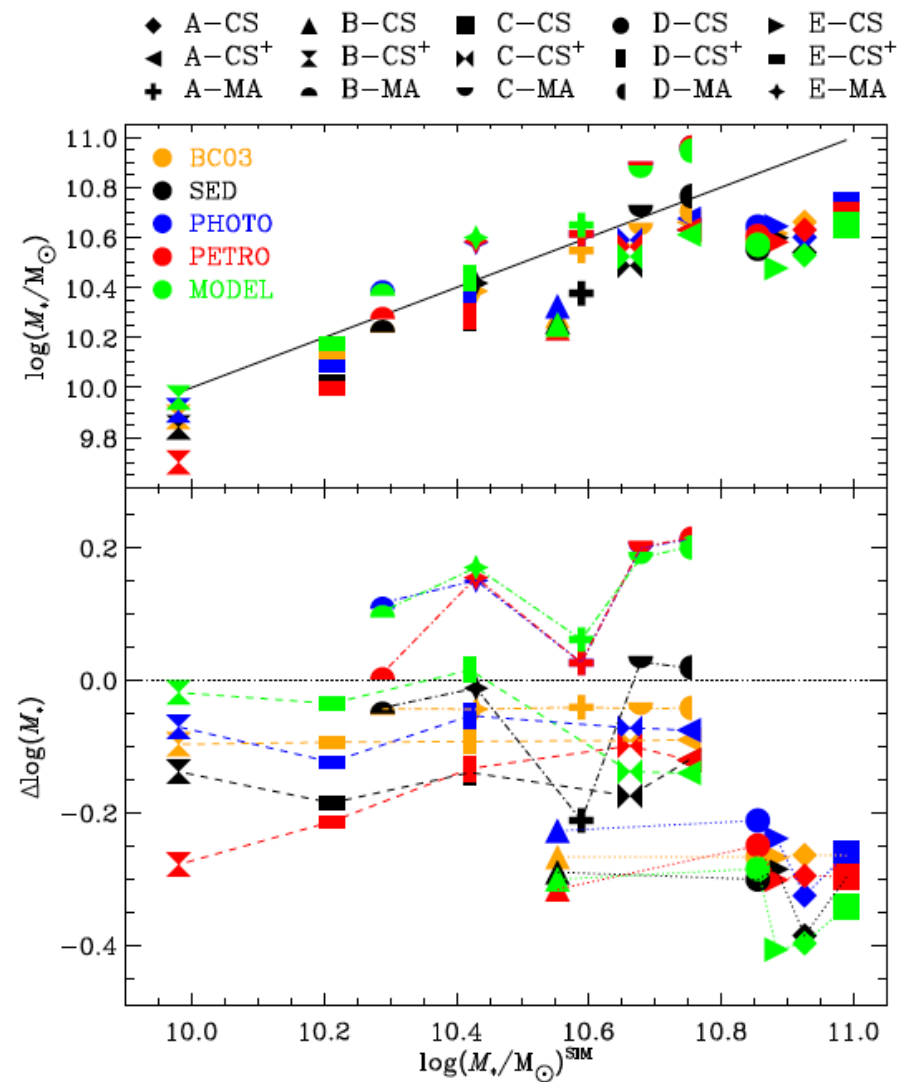
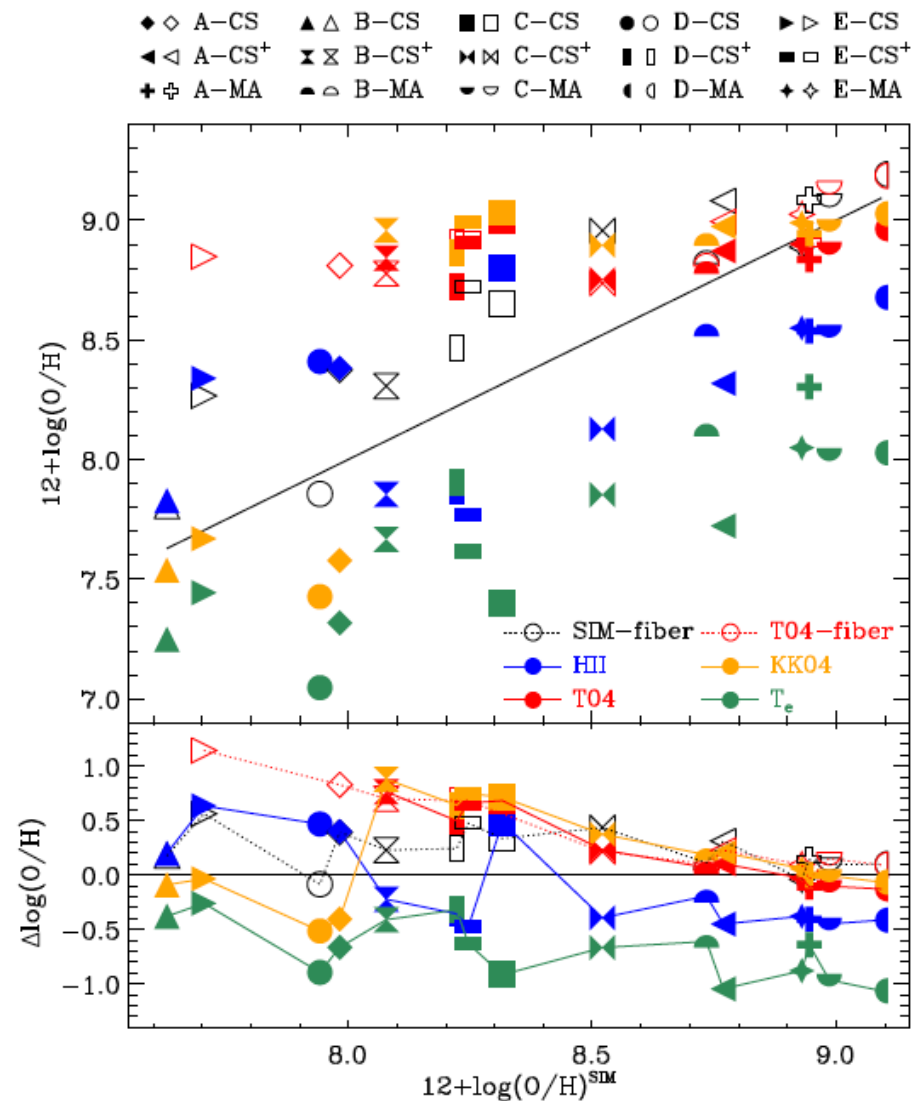
we found large differences!

So ... don't simply tell me if your galaxy is realistic or not, tell me which method have you used to make the comparison and I can decide how good your code is!!!

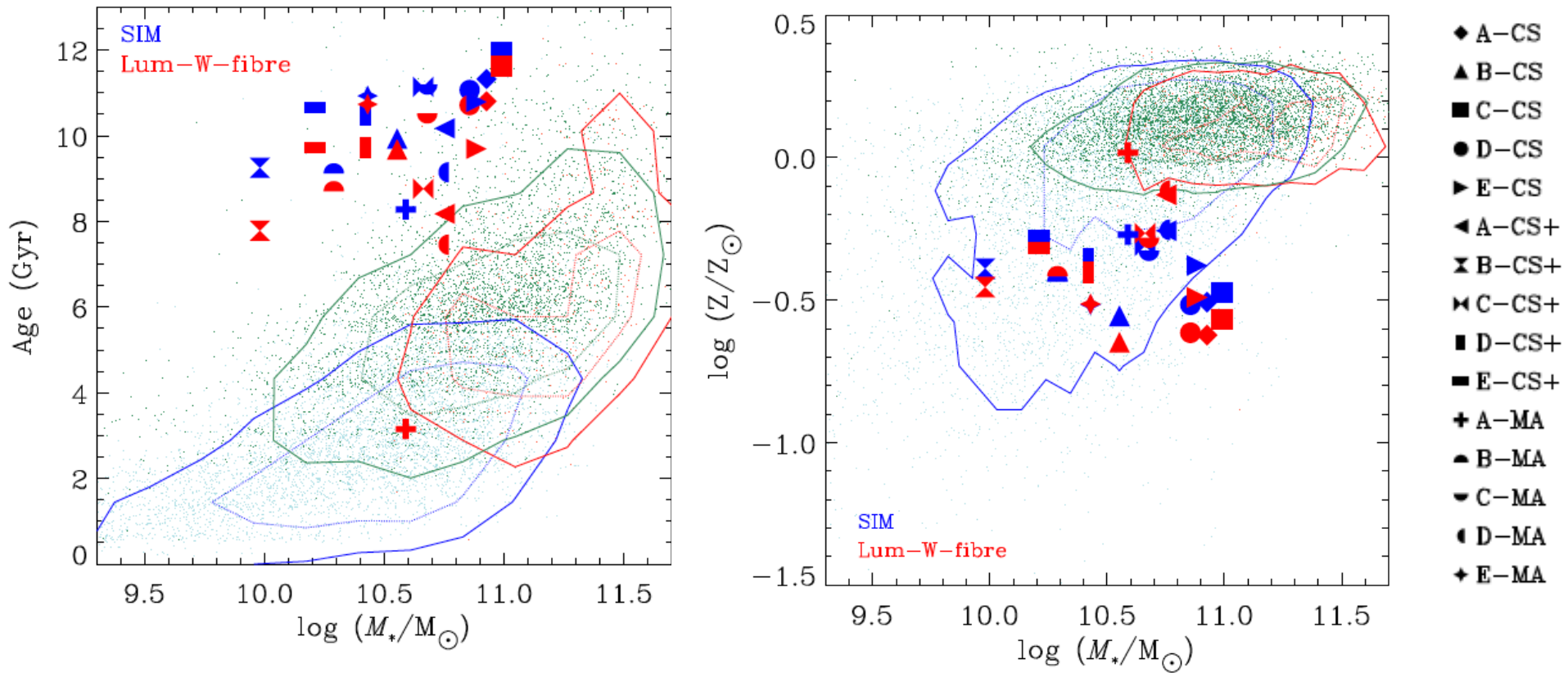
Variations among methods



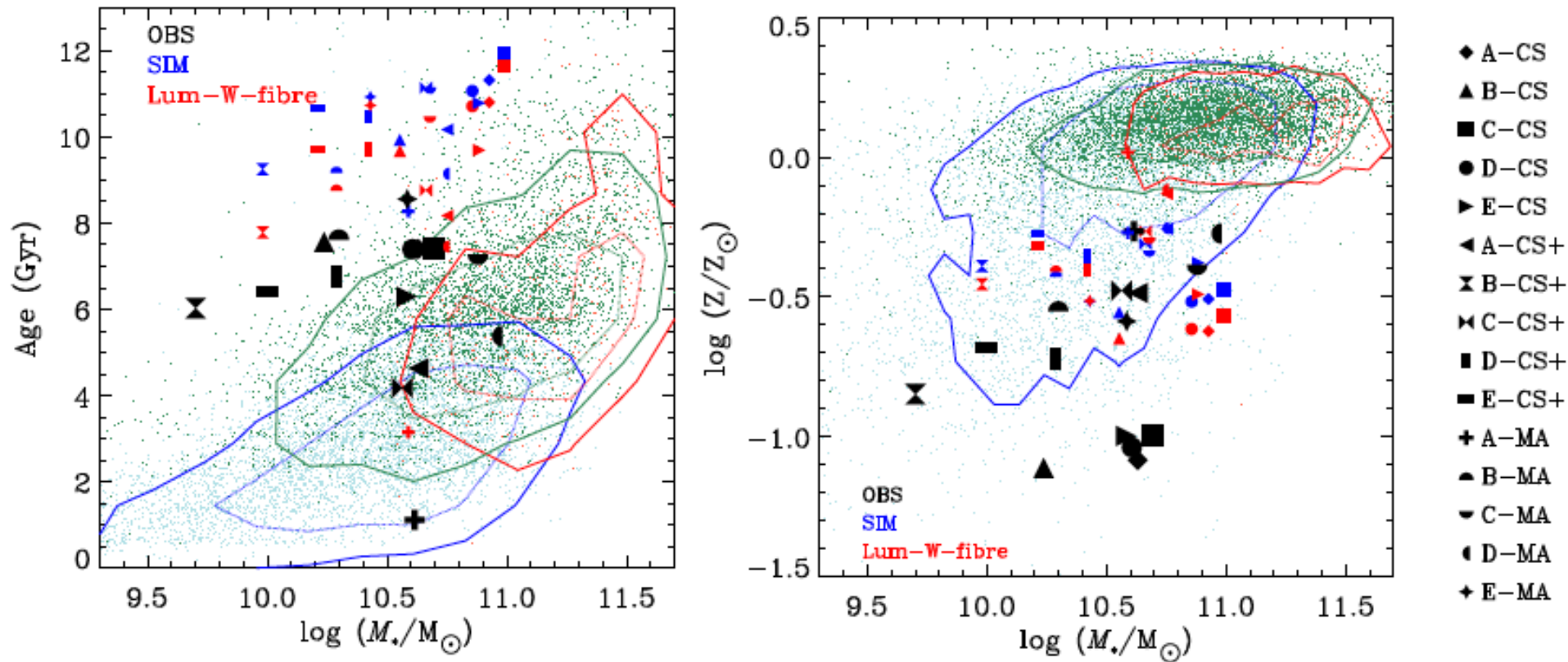
Variations among methods



Results V: Simulations vs observations

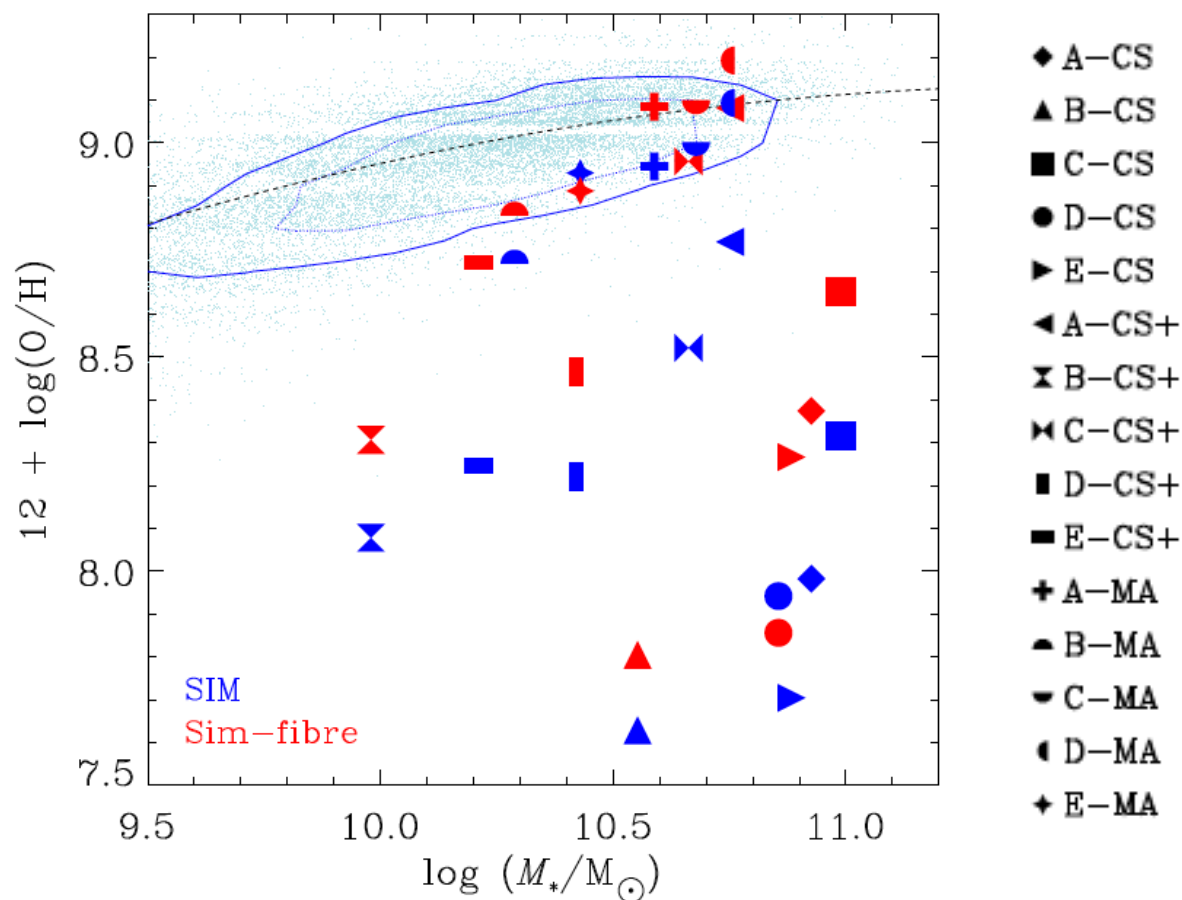


Results V: Simulations vs observations

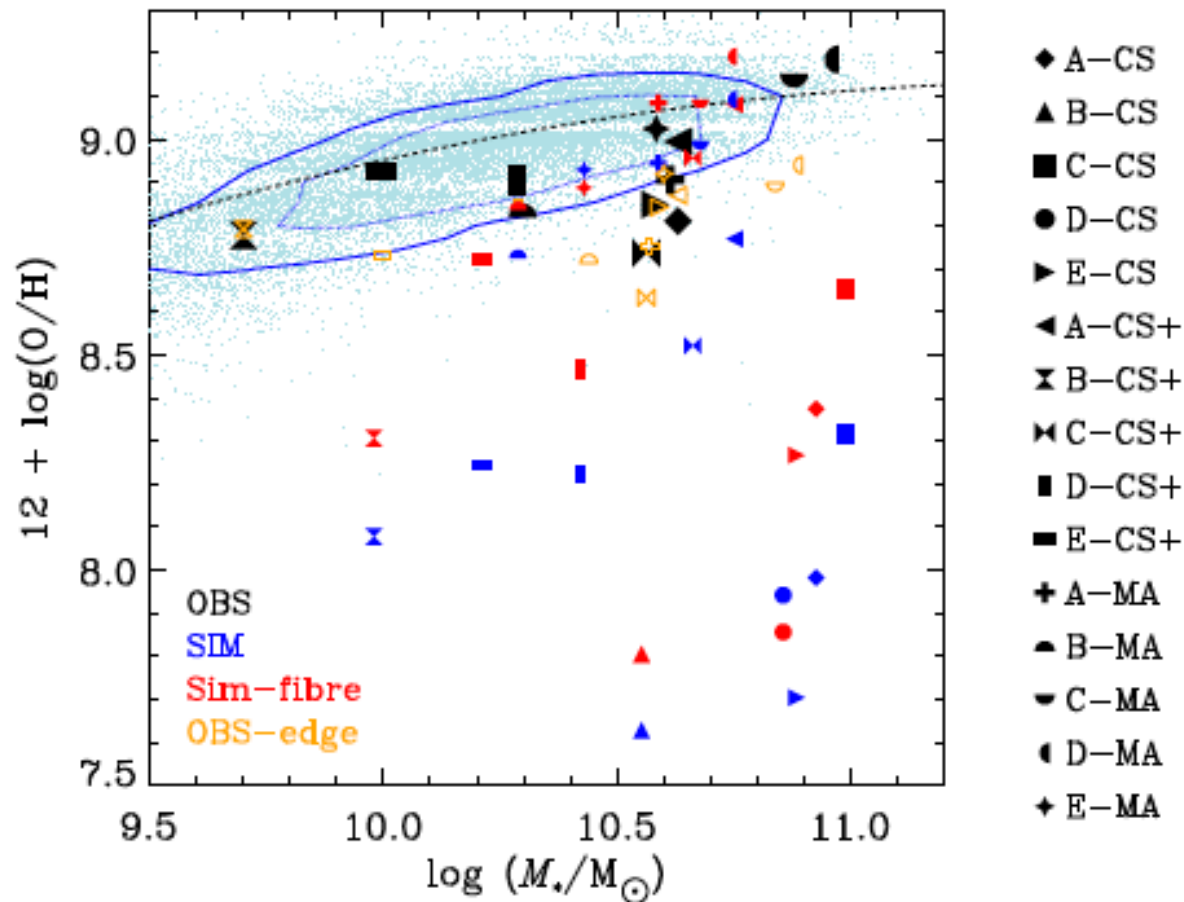


- Simulated galaxies look older than observed ones (but remember comparison not fully reliable)
- Simulated galaxies are more metal-poor than observed ones, but still compatible to low-metallicity spiral galaxies

Results V: Simulations vs observations

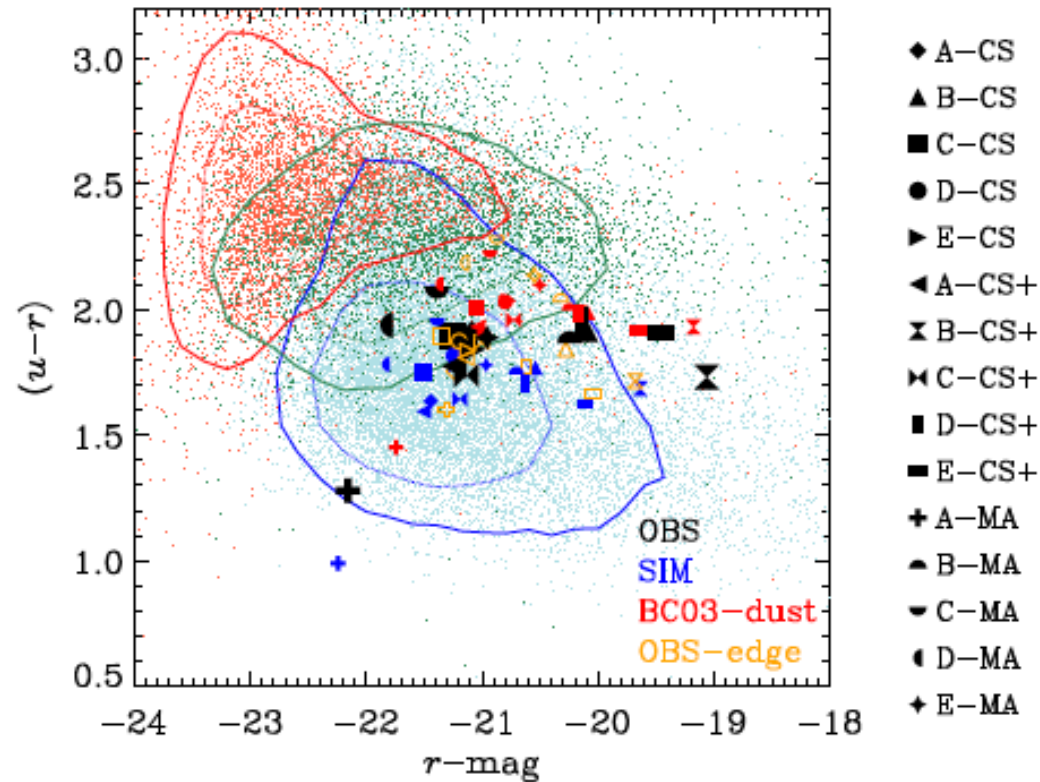
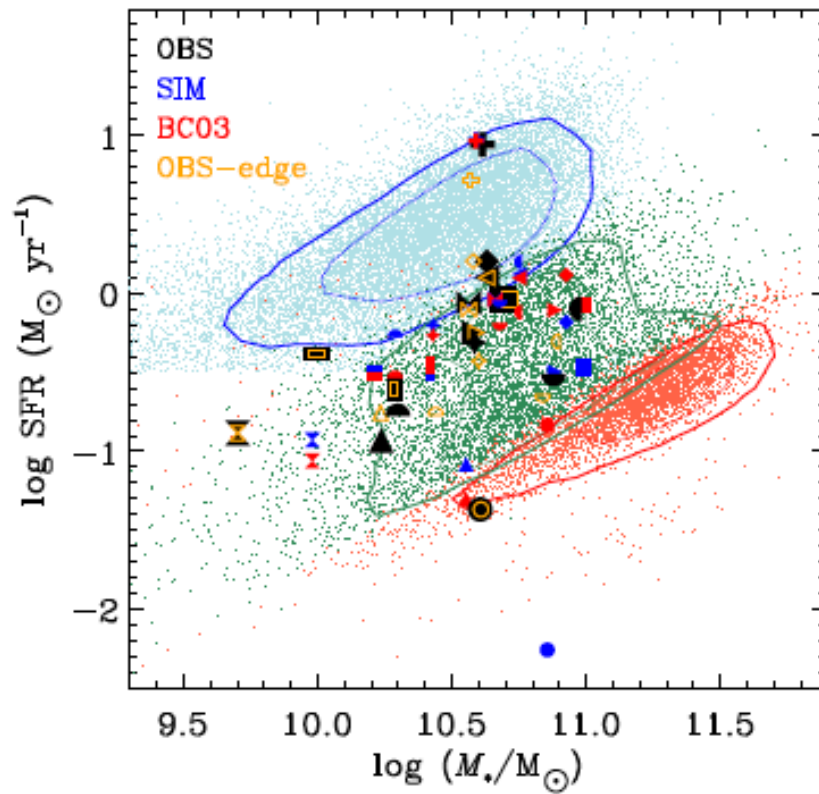


Results V: Simulations vs observations



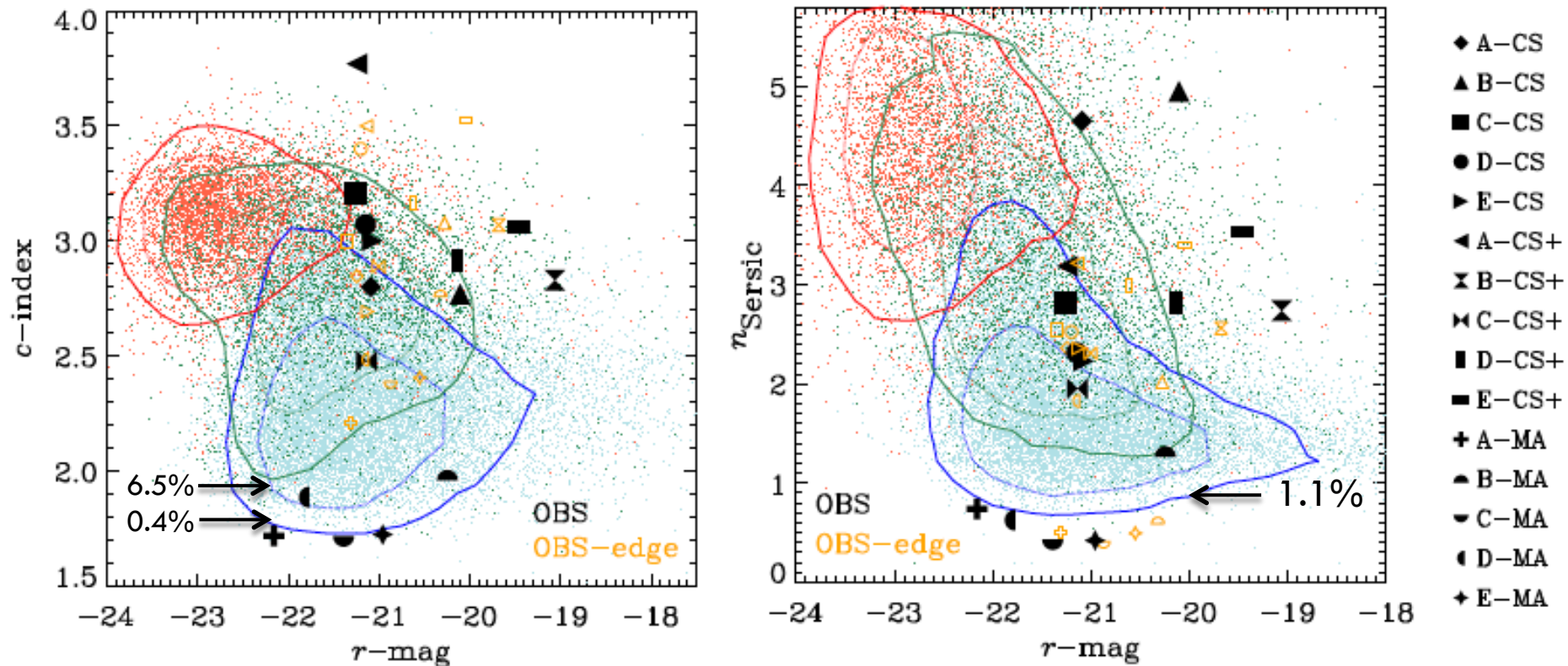
- Simulated galaxies have similar oxygen abundances compared to observations.

Results V: Simulations vs observations



- The SFRs of simulated galaxies are consistent with blue/green valley SDSS galaxies
- Colours and magnitudes of simulated galaxies are also consistent with blue/green valley galaxies

Results V: Simulations vs observations



- Simulated galaxies have c-indices and n_{Sersic} consistent with the data
- But: MA-galaxies have very low concentrations and Sersic indices, CS and CS+ samples are higher and more diverse

Summary

- *A reliable comparison between simulated and observed galaxies requires that the corresponding observational biases are properly taken into account.*
- Our simulated galaxies are in general consistent with SDSS blue/green valley galaxies, but tend to be older and more metal-poor.
- We could use scaling relations to “convert” the simulation values into quantities that can be compared with observations in an unbiased manner.
- We need to test if the same scalings work with other simulations/codes?