Connection between dark matter and galaxy stellar mass growth

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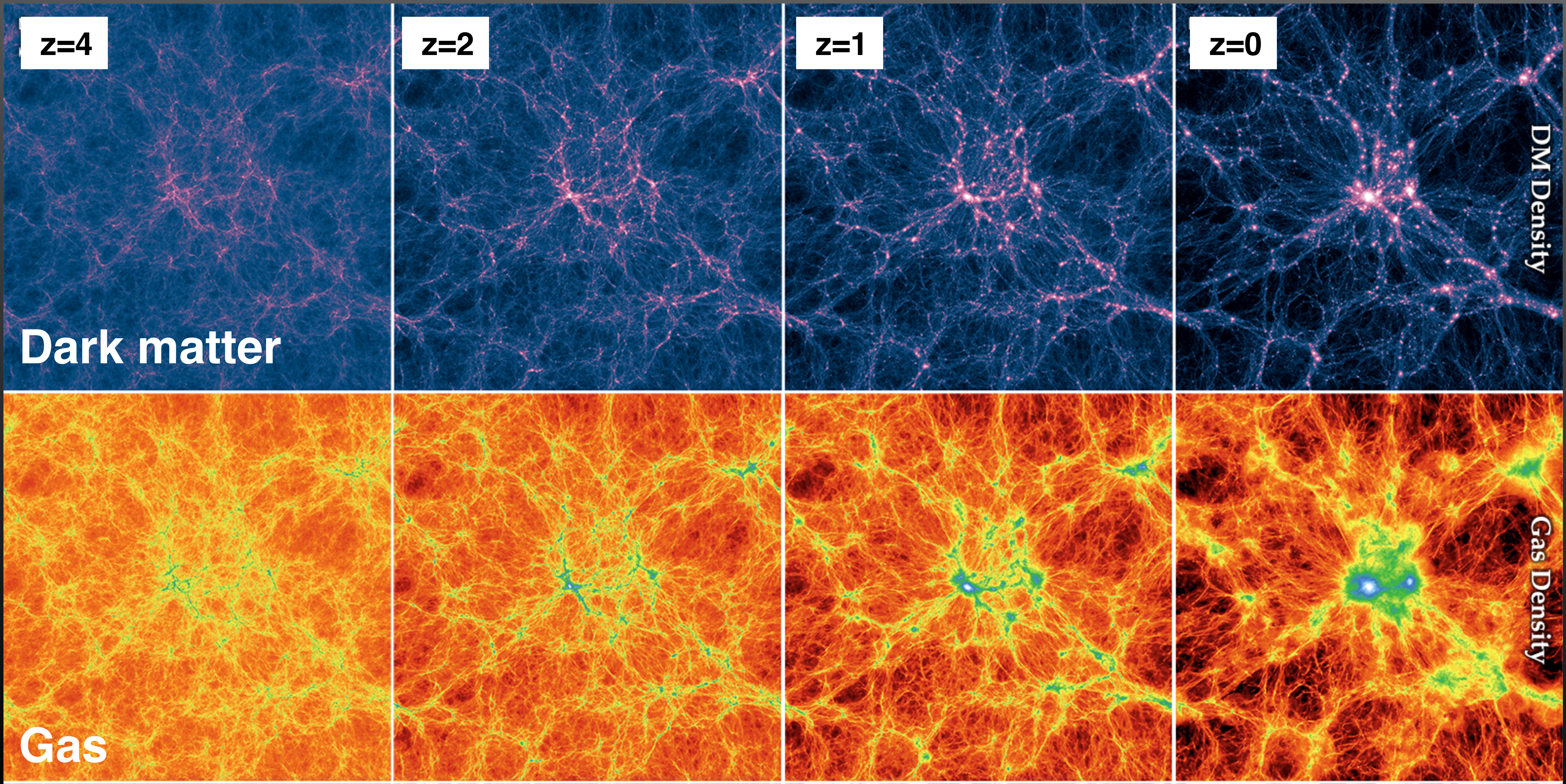
Why such connection?

As the dark matter halos accrete at a rate M'_{DM}, baryonic gas is accreted too

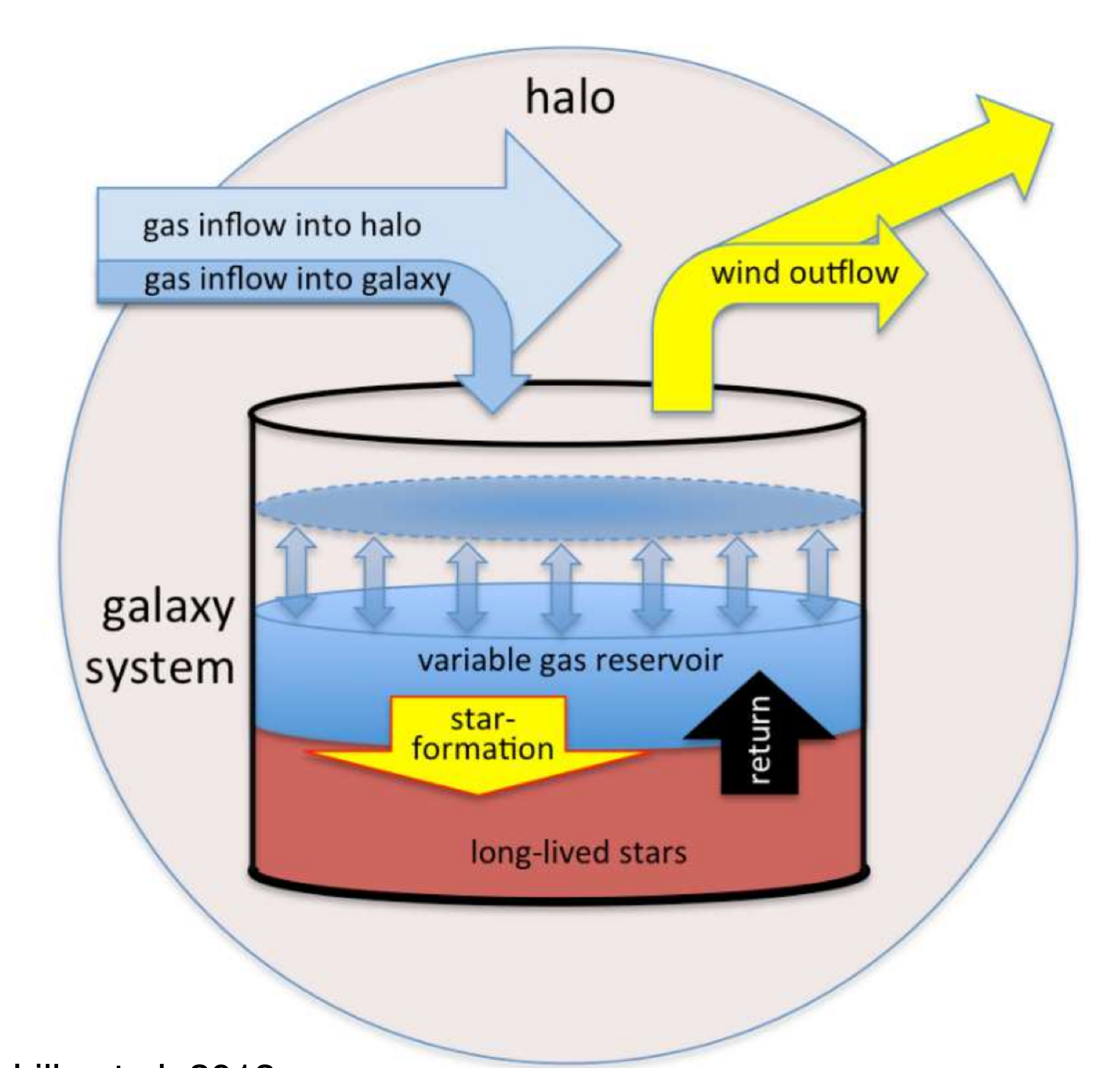
➢ fuel for star formation



Illustris simulation

Simple physical models

Stellar mass growth SFR/$M_{☆}$ driven by dark matter halo increase rate M'_{DM}/M_{DM}



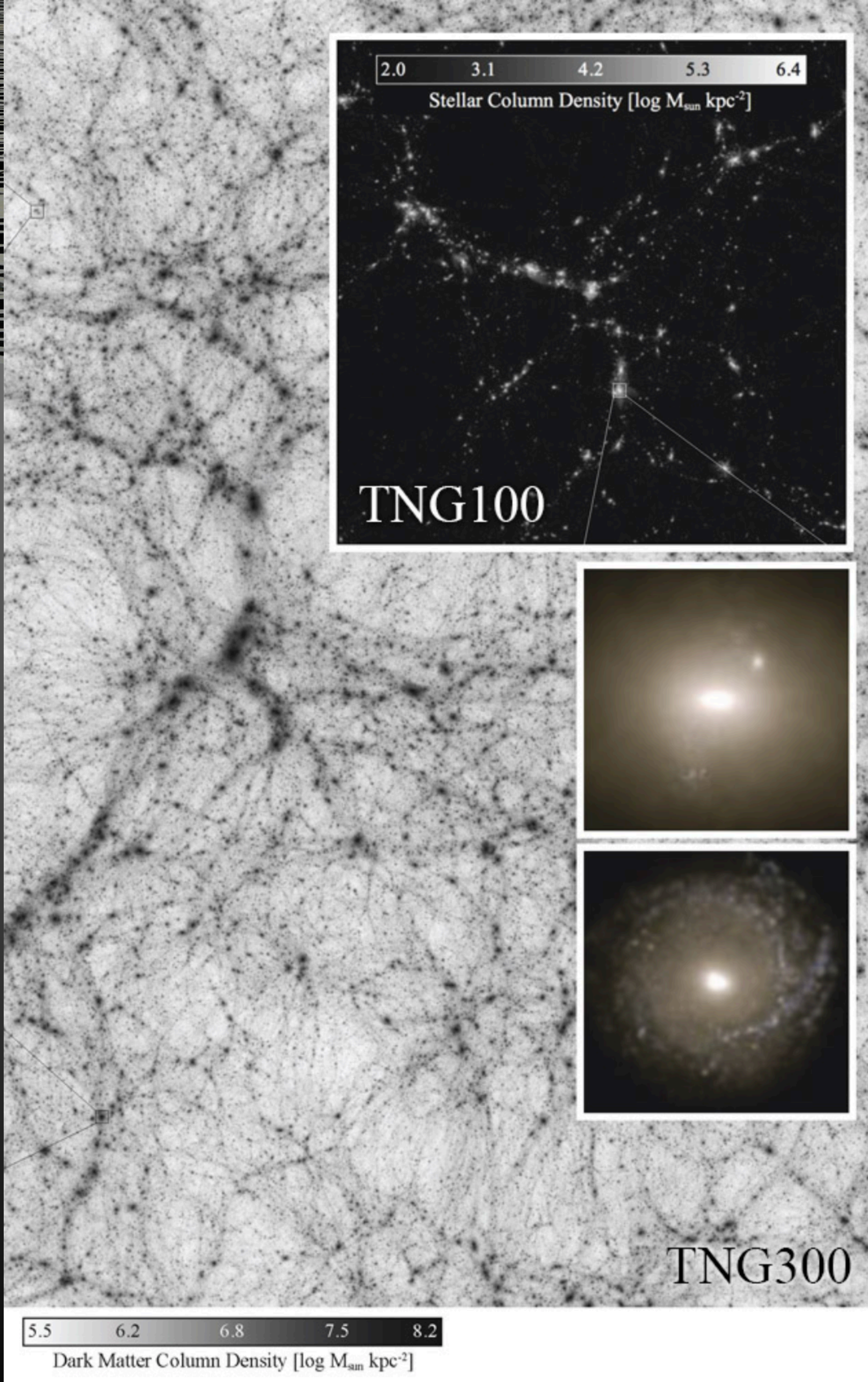
Lilly et al. 2013

cosmological simulations

Create mock galaxy catalogues from cosmological simulations
Illustris TNG, Horizon-AGN, EAGLE, …

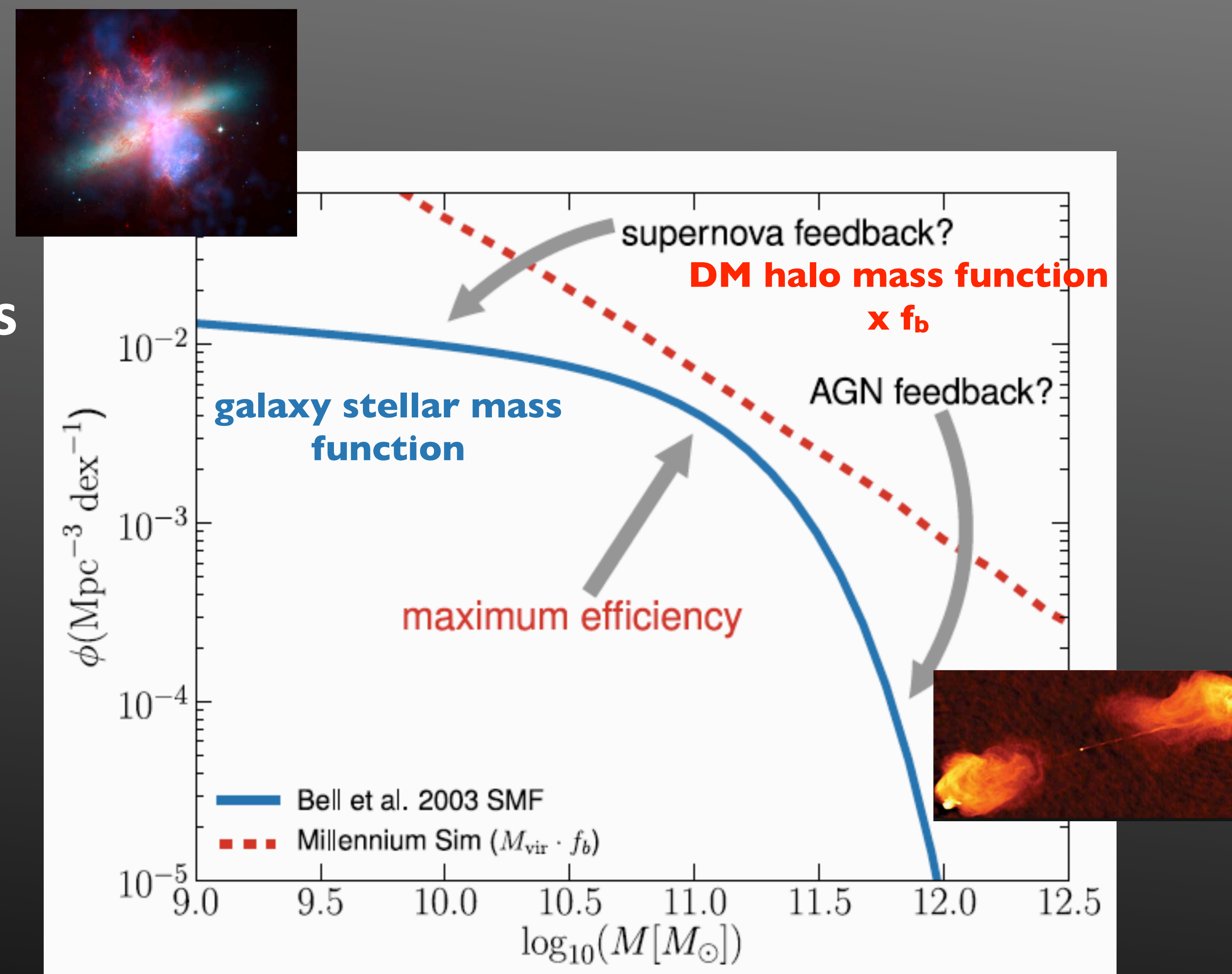
Follow DM, gas, stellar particules

But because of the resolution, sub-grid physics should be adjusted



Some observational contraints from galaxy surveys

Learn from the different distributions of the DM halo mass and galaxy stellar masses

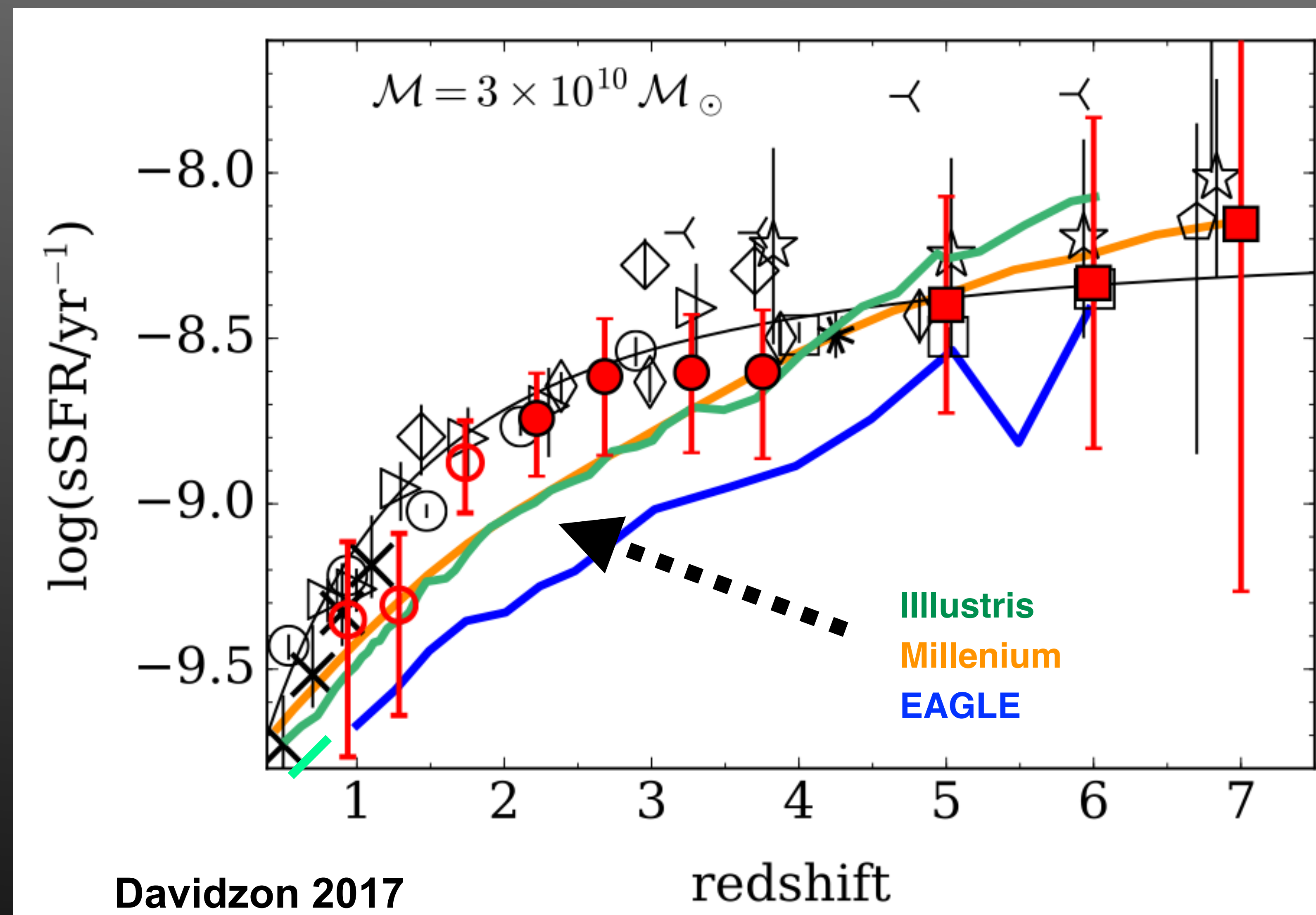


Mutch et al. 2013

Lilly et al. 2013

Some observational contraints from galaxy surveys

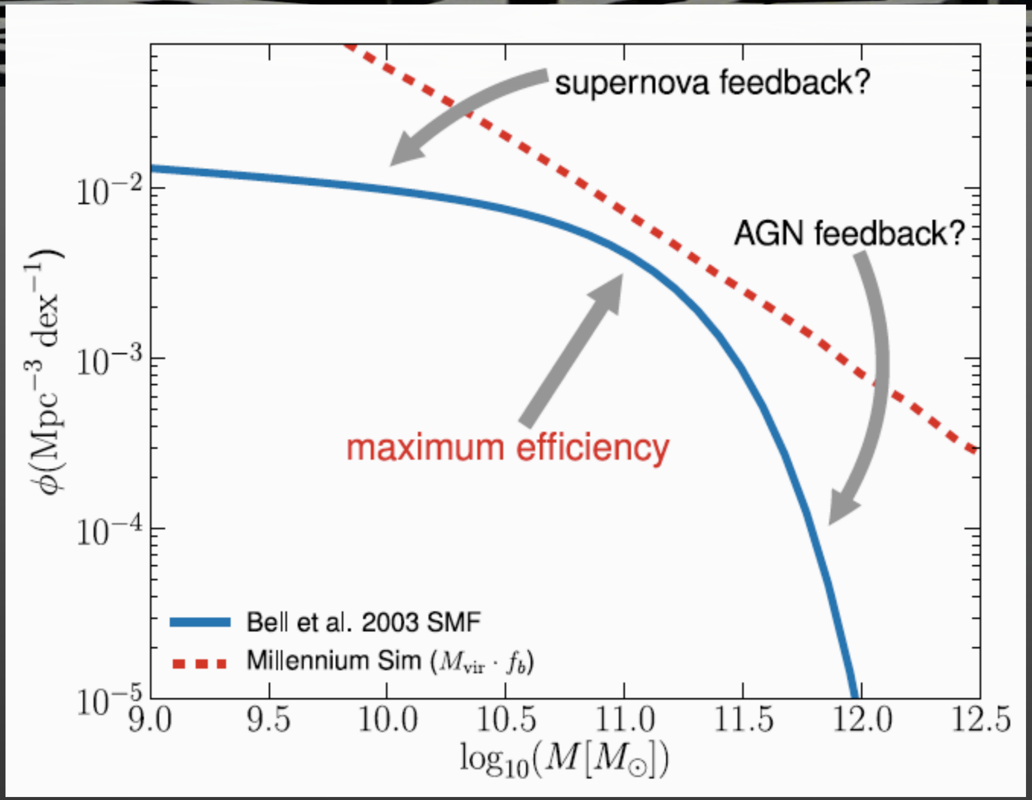
Evolution of the specific SFR
SFR/M☆



Does SFR/M☆ follow M'_{DM}/M_{DM} ?

Lilly et al. 2013

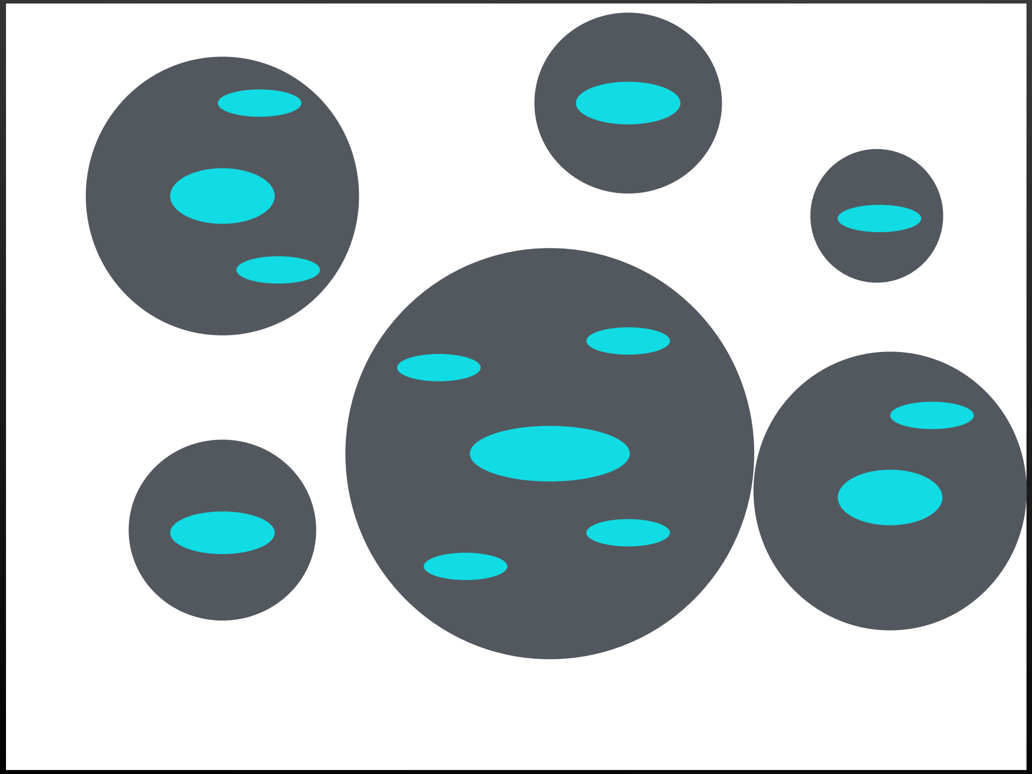
Probe the halo-galaxy connection with COSMOS2020



Galaxy stellar mass function at high redshift

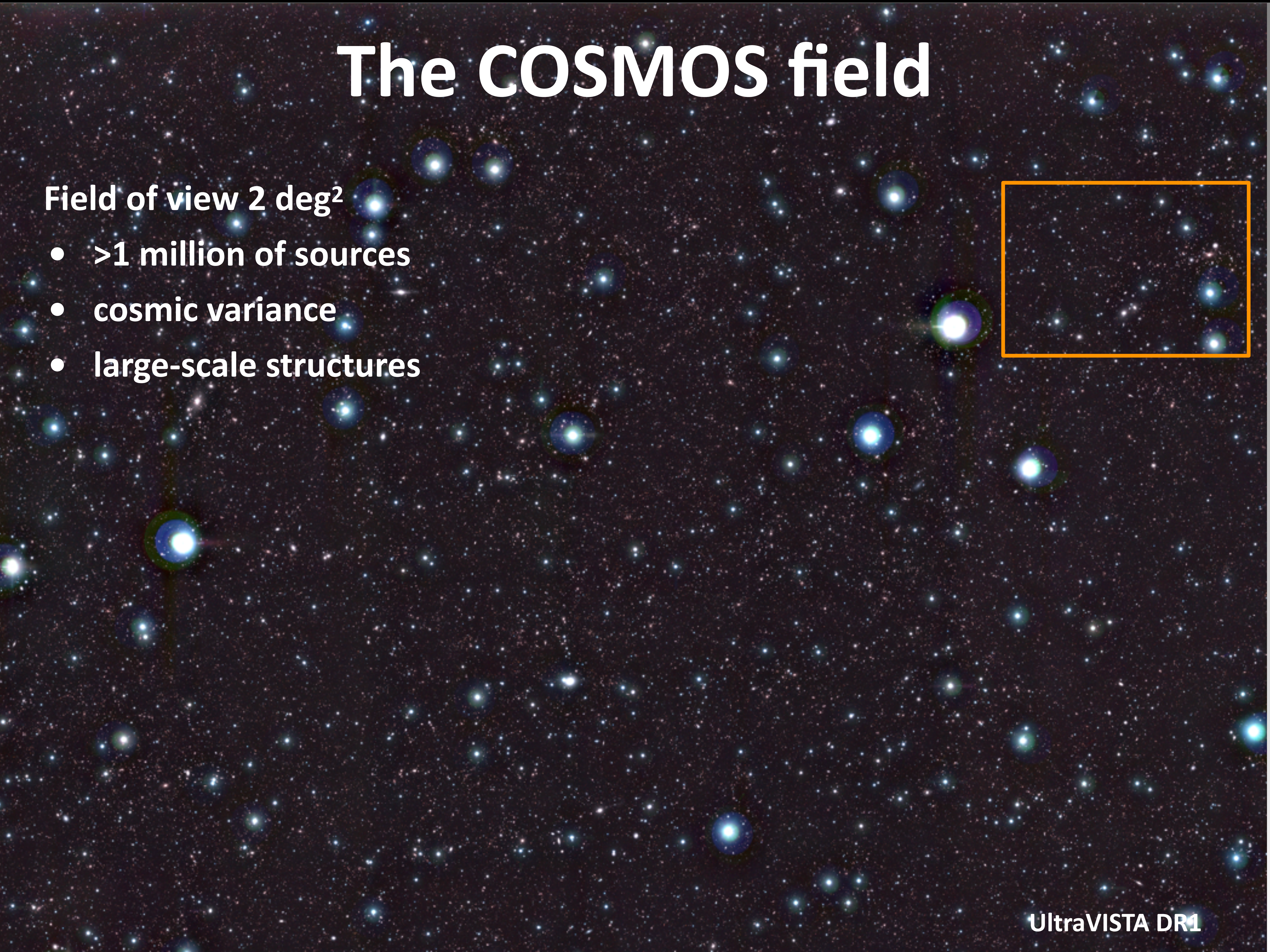
- When feedback became effective ?
- How fast is the gas converted into stars ?

Weaver et al. , in prep



Probe the DM halo and galaxy stellar mass connection using Halo Occupation Distribution (HOD) model

Shuntov et al. 2022


The COSMOS field
Field of view 2 deg²
• >1 million of sources
• cosmic variance
• large-scale structures
UltraVISTA DR1

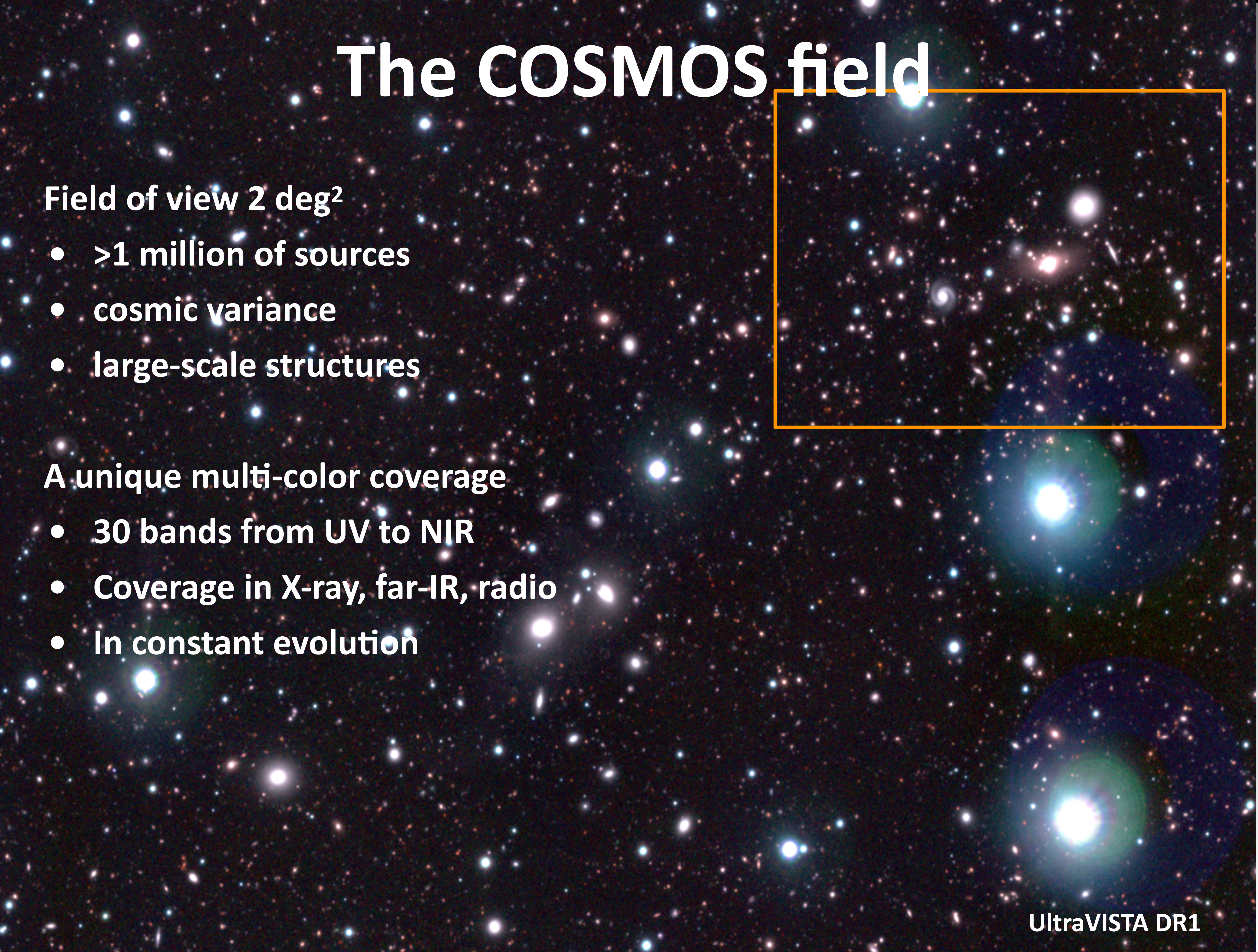
The COSMOS field

Field of view 2 deg^2

- >1 million of sources
- cosmic variance
- large-scale structures

A unique multi-color coverage

- 30 bands from UV to NIR
- Coverage in X-ray, far-IR, radio
- In constant evolution



The COSMOS field

Field of view 2 deg²

- >1 million of sources
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A unique multi-color coverage

- 30 bands from UV to NIR
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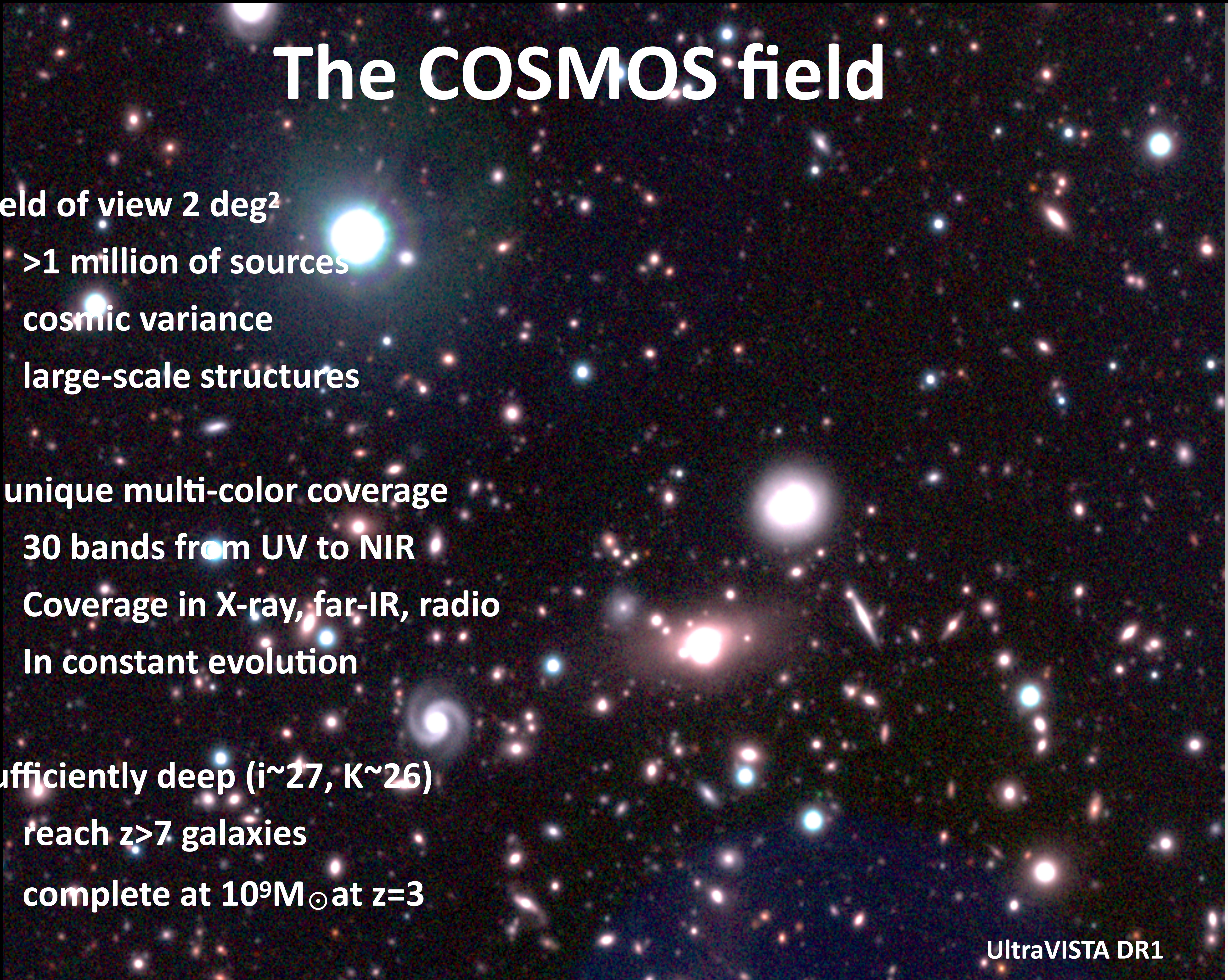
Sufficiently deep (i~27, K~26)

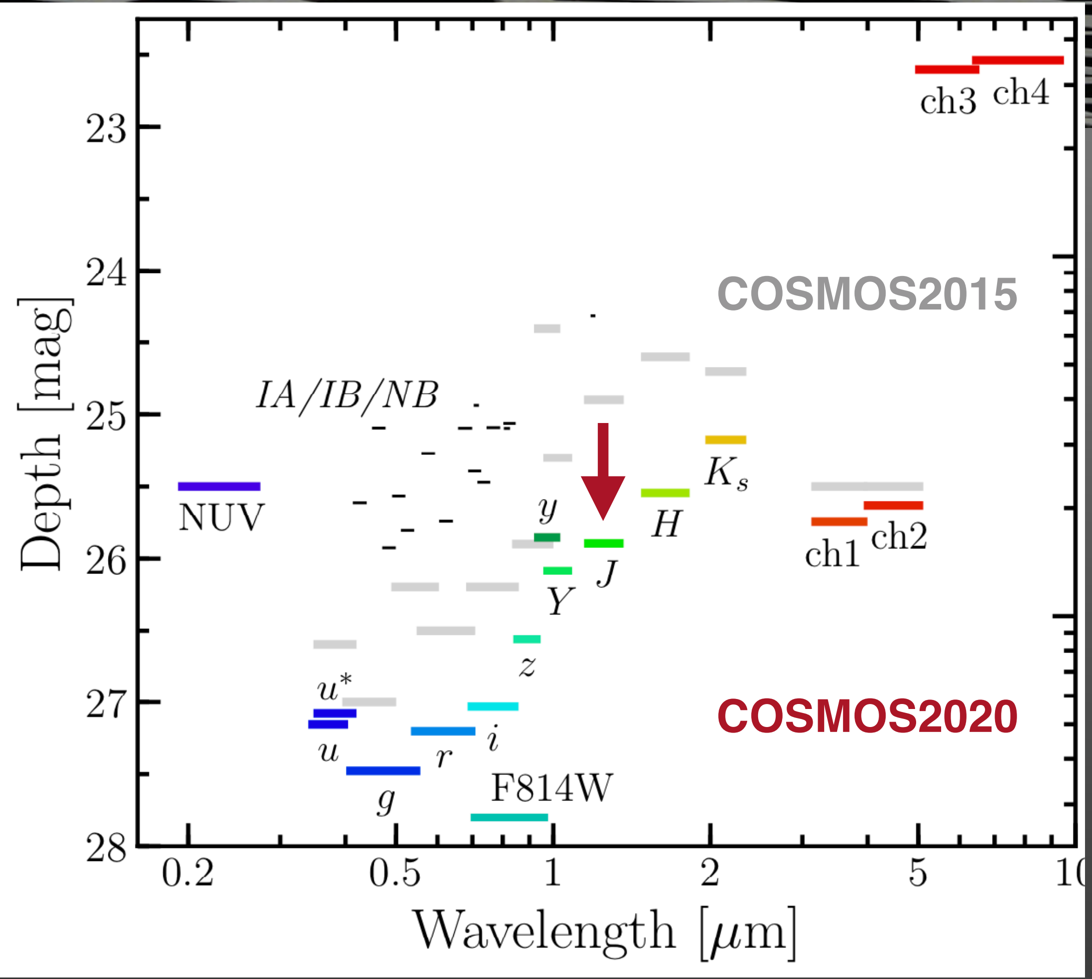
- reach z>7 galaxies
- complete at $10^9 M_\odot$ at z=3



UltraVISTA DR1

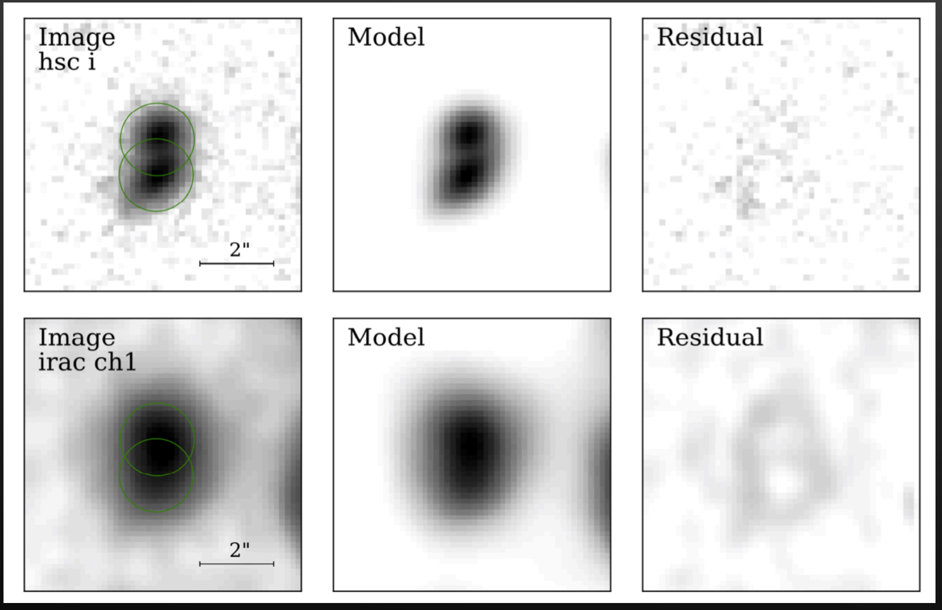
The COSMOS2020 catalogues

Weaver et al. 2022



Two photometric catalogues
with > 1 million of sources

<u>Classic</u>
Aperture photometry
<u>The Farmer</u>
Fit parametric surface-brightness profiles



Everything public
https://cosmos2020.calet.org/catalogues/

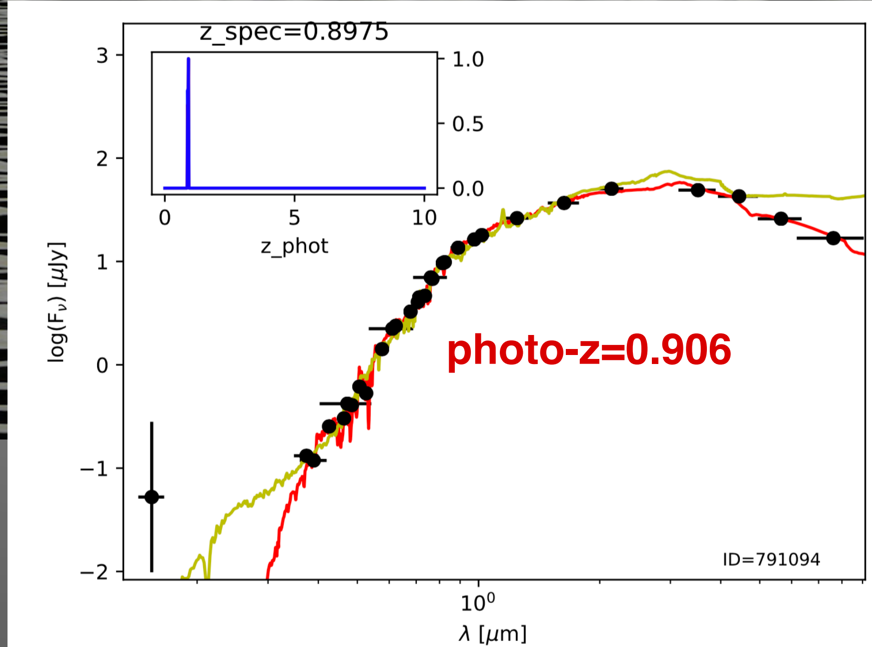
COSMOS2020 photometric redshifts

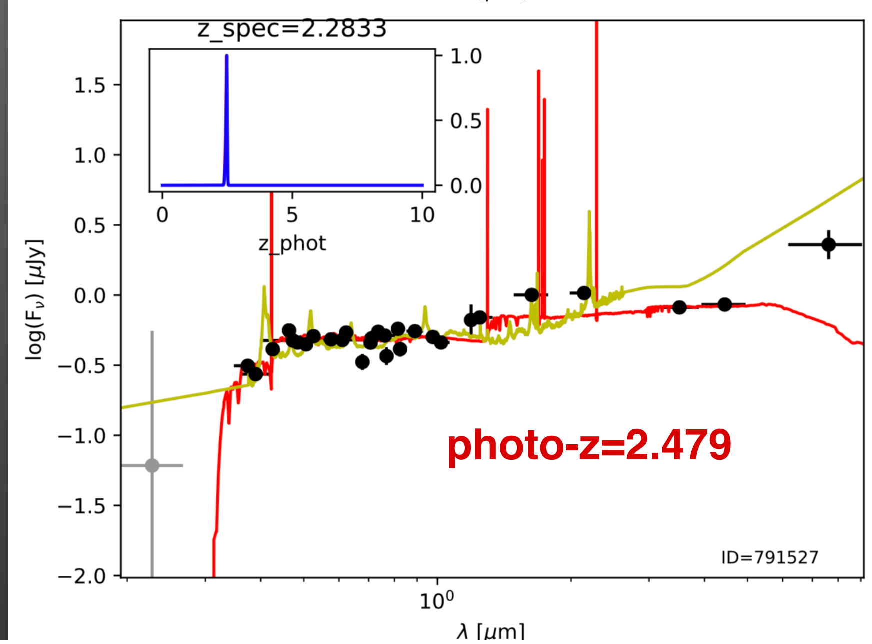
Le Phare++

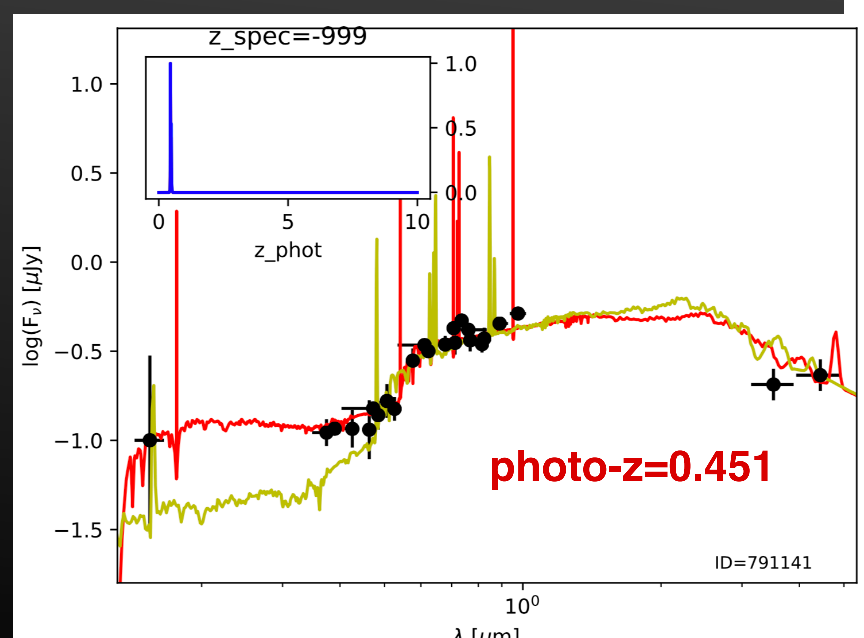
https://gitlab.lam.fr/Galaxies/LEPHARE/-/releases

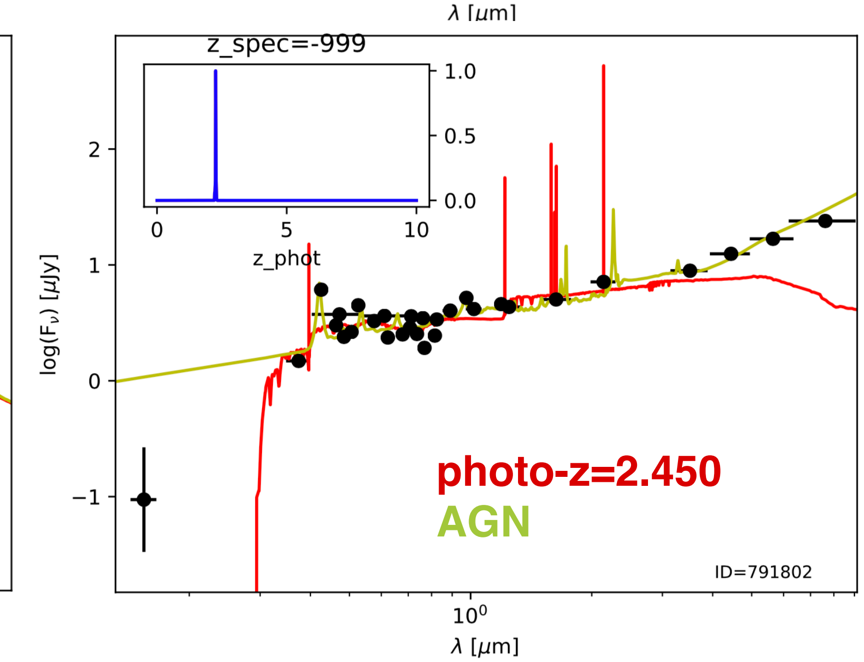
- **Template-fitting (galaxies, AGN, stars)**
- **Combine several dust attenuation laws**
- **Include emission lines**
- **…**

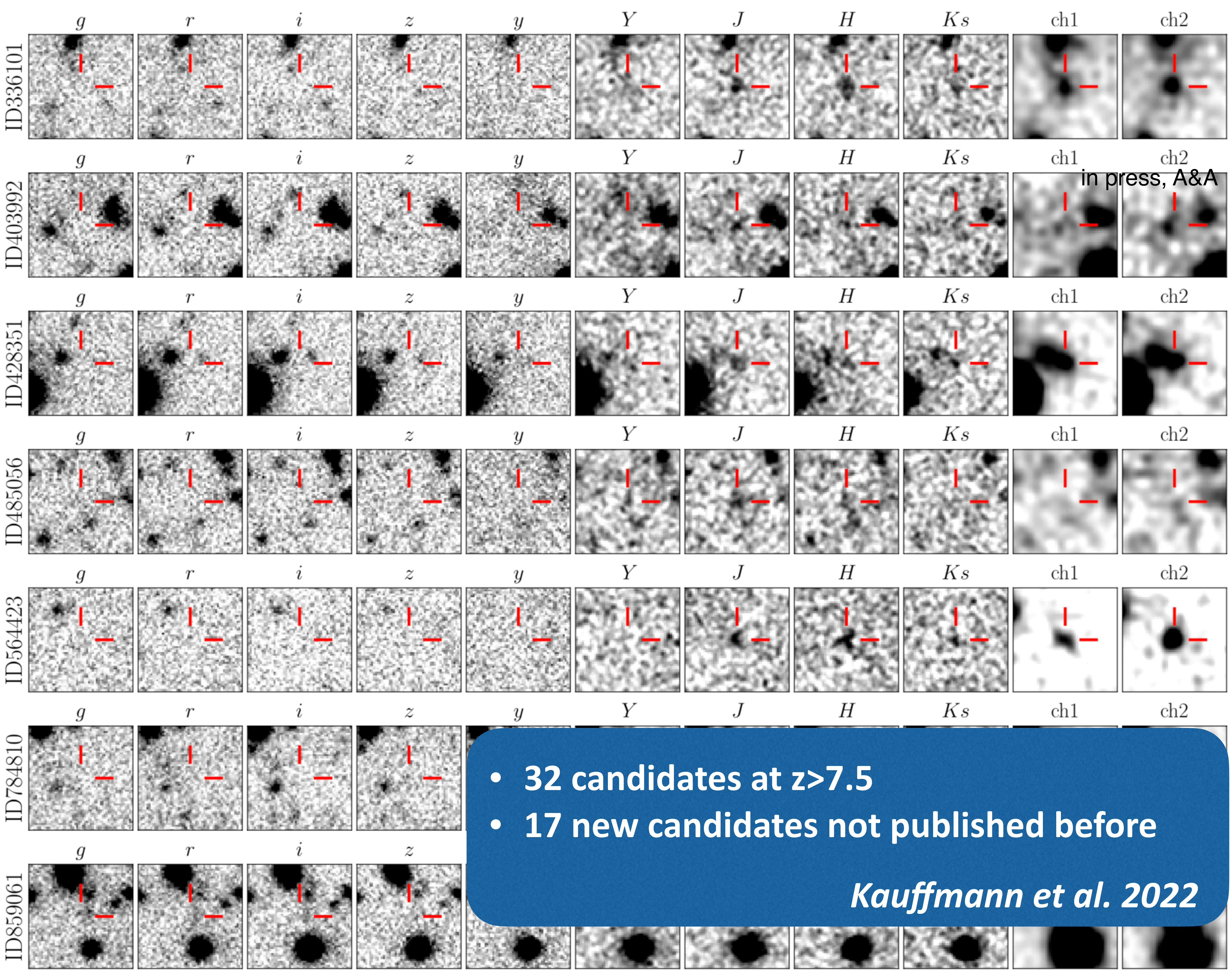
Second version with Eazy









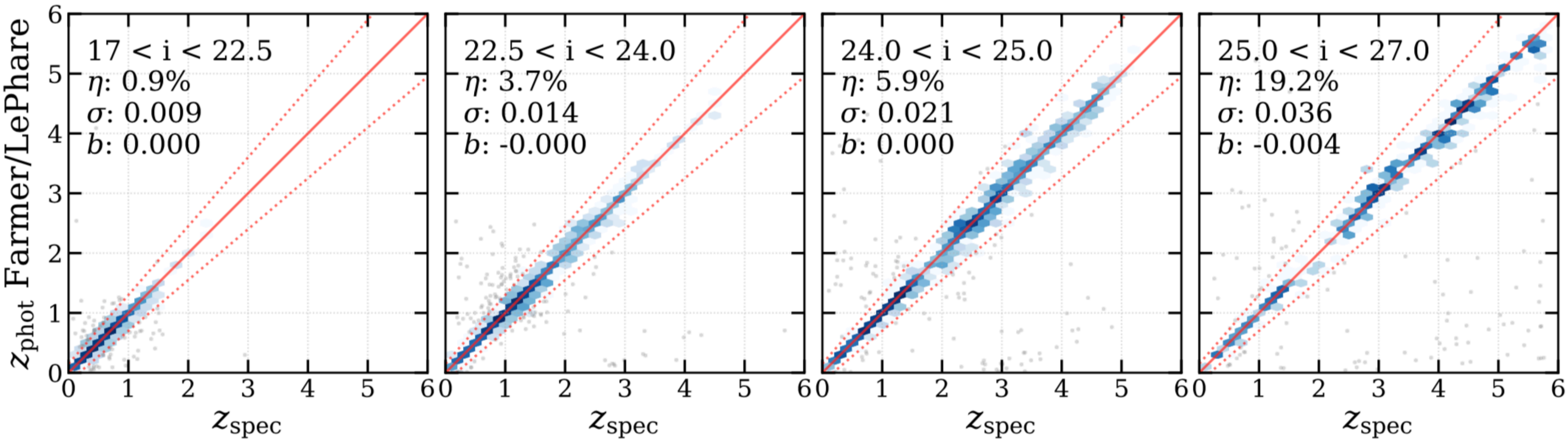


- **32 candidates at z>7.5**
- **17 new candidates not published before**

Kauffmann et al. 2022

COSMOS2020 photometric redshifts

Weaver et al. 2022

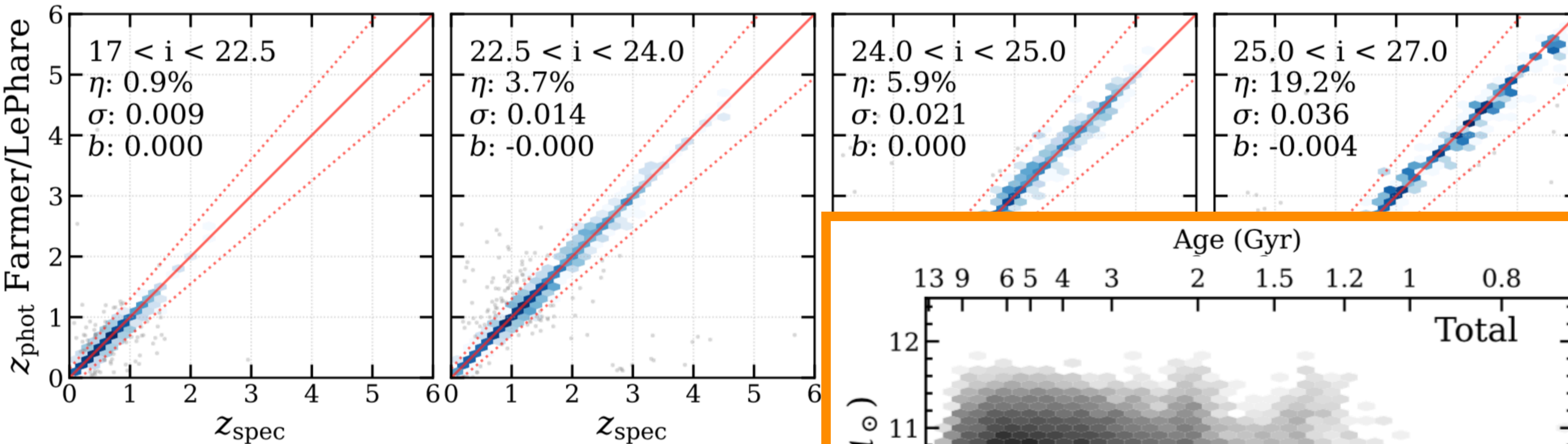


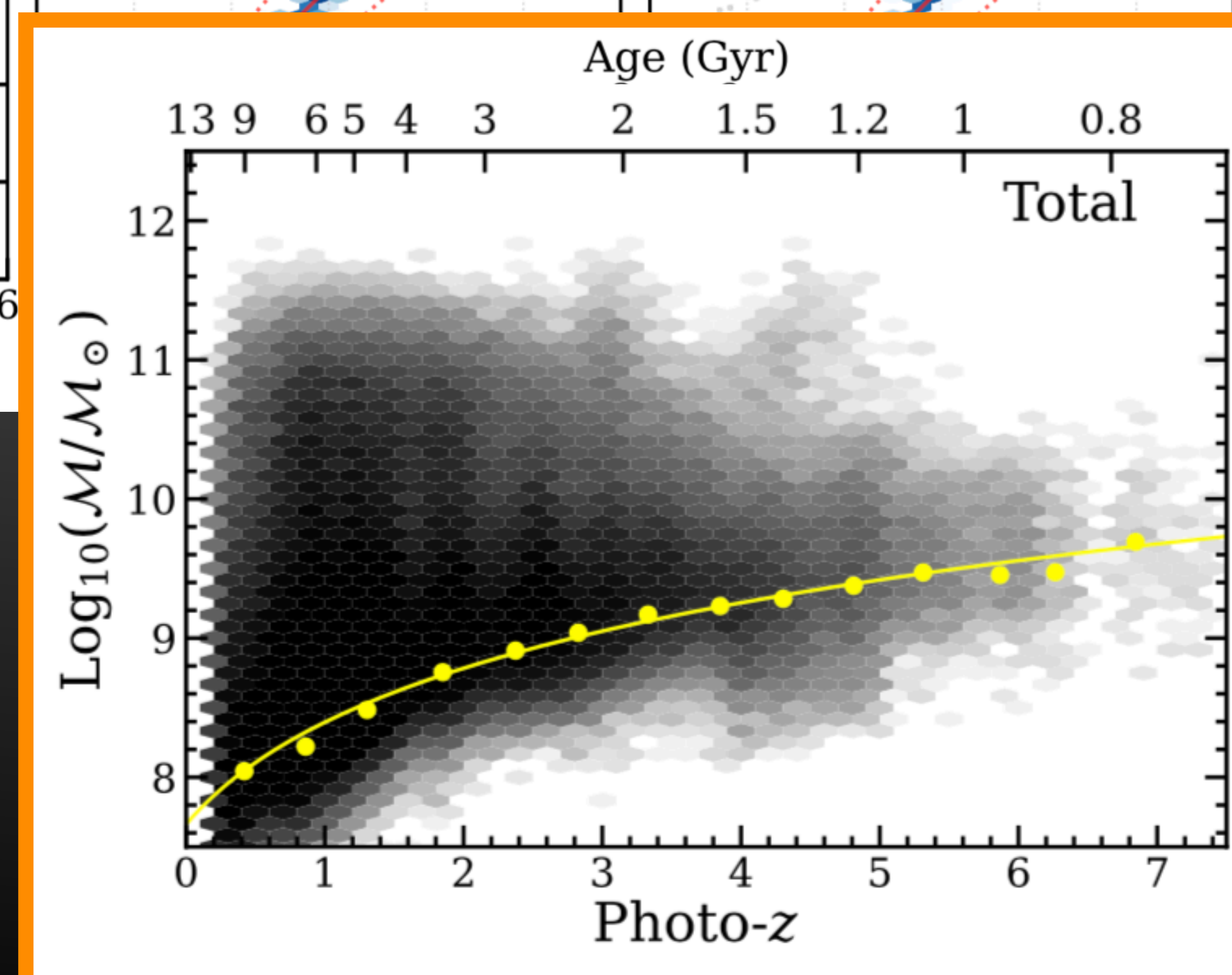
1% precision at i<22.5

4-5% precision at 25<i<26

COSMOS2020 photometric redshifts

Weaver et al. 2022

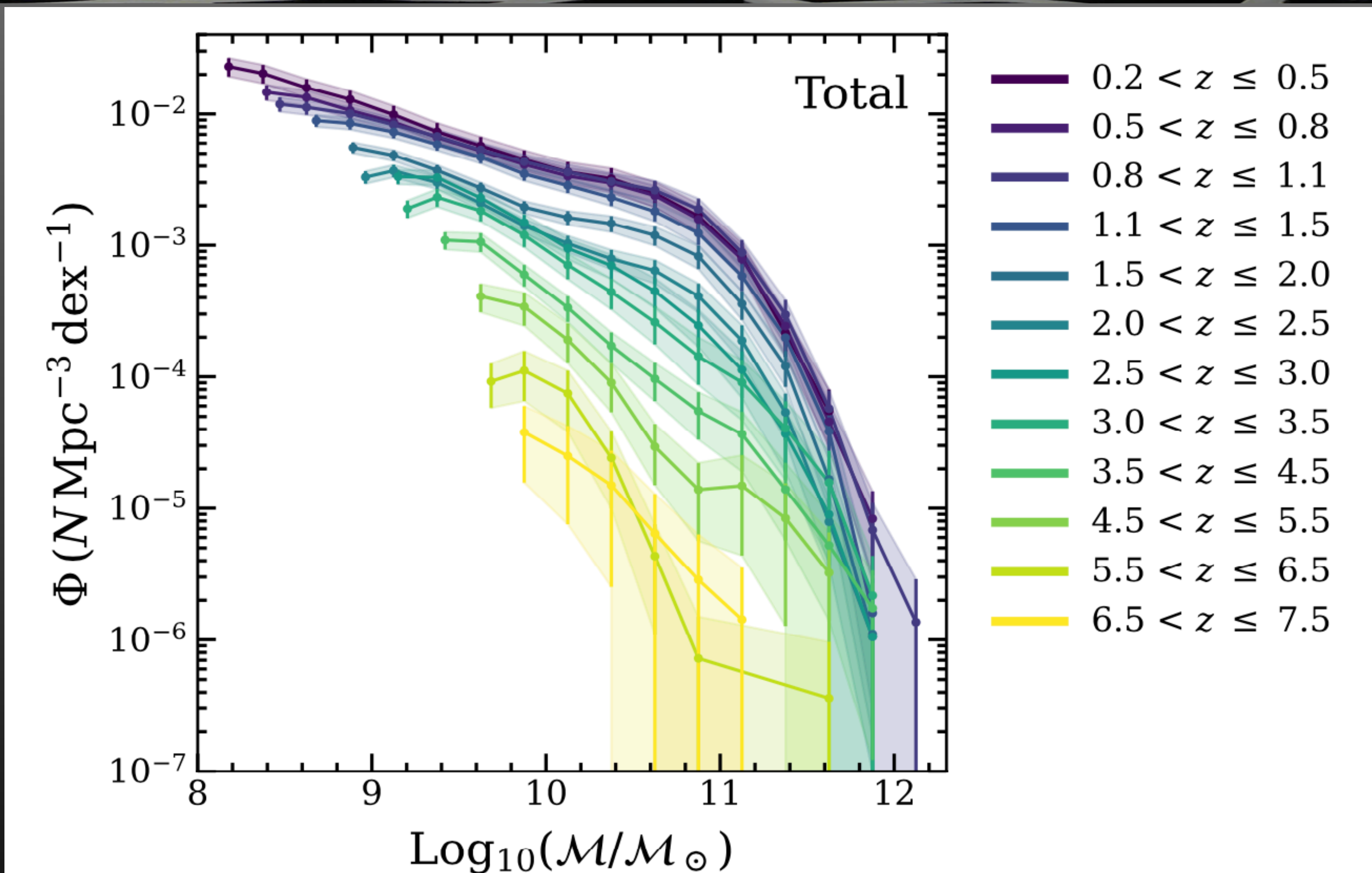




Galaxy stellar masses established from SED-fitting

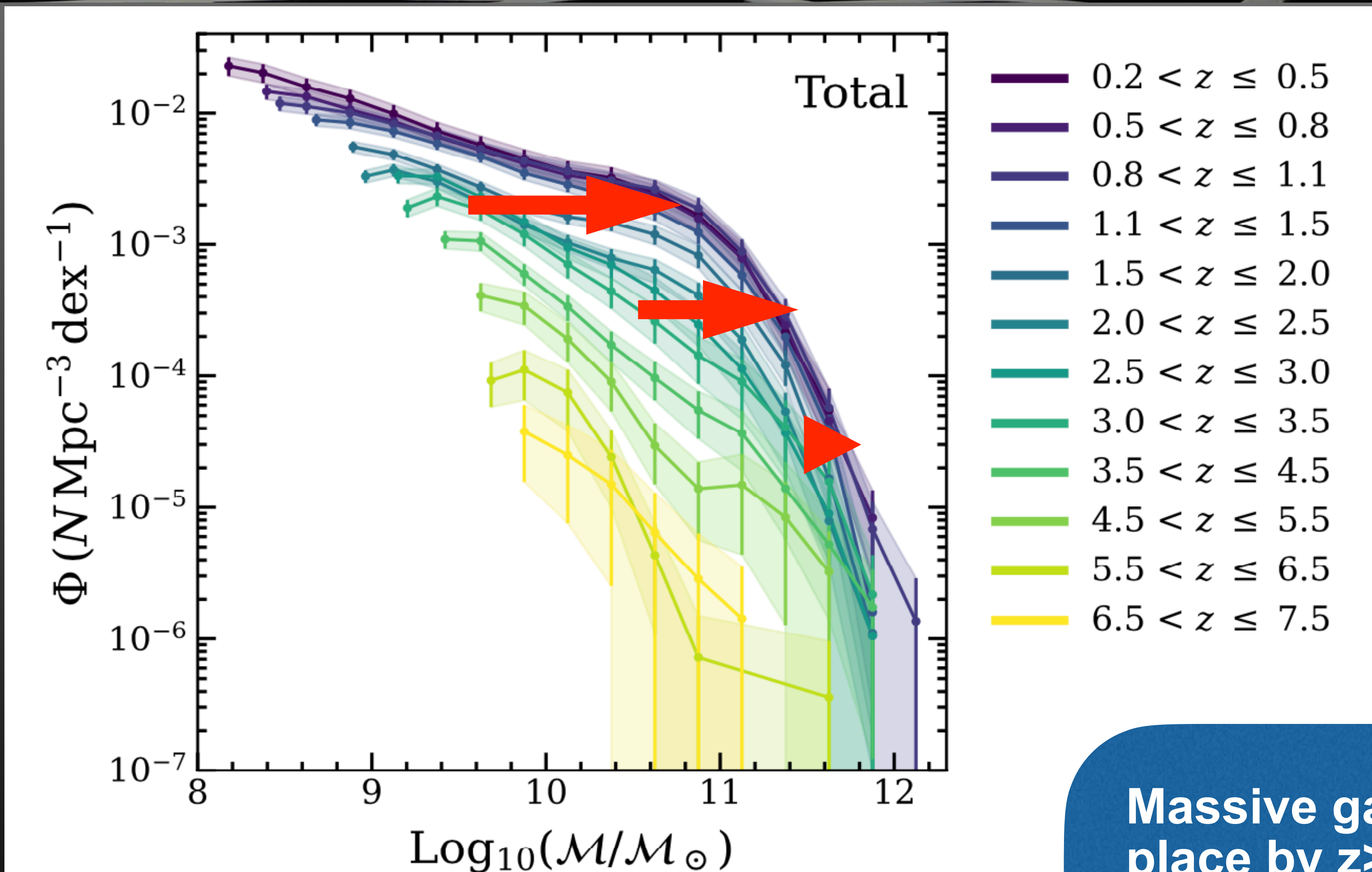
The galaxy stellar mass function

Weaver et al., in prep



The galaxy stellar mass function

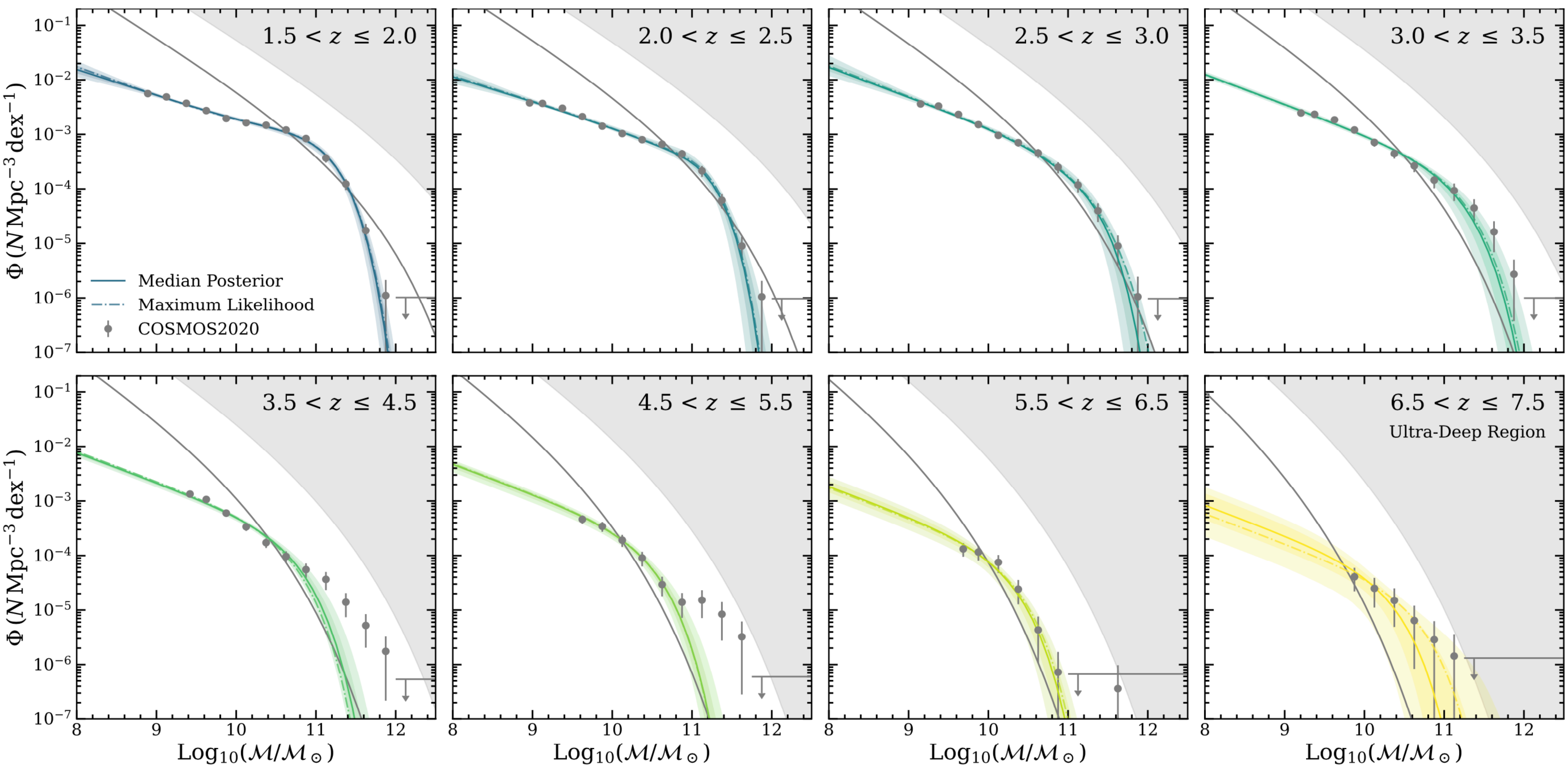
Weaver et al., in prep



Massive galaxies already in place by z>4

➢ quenching

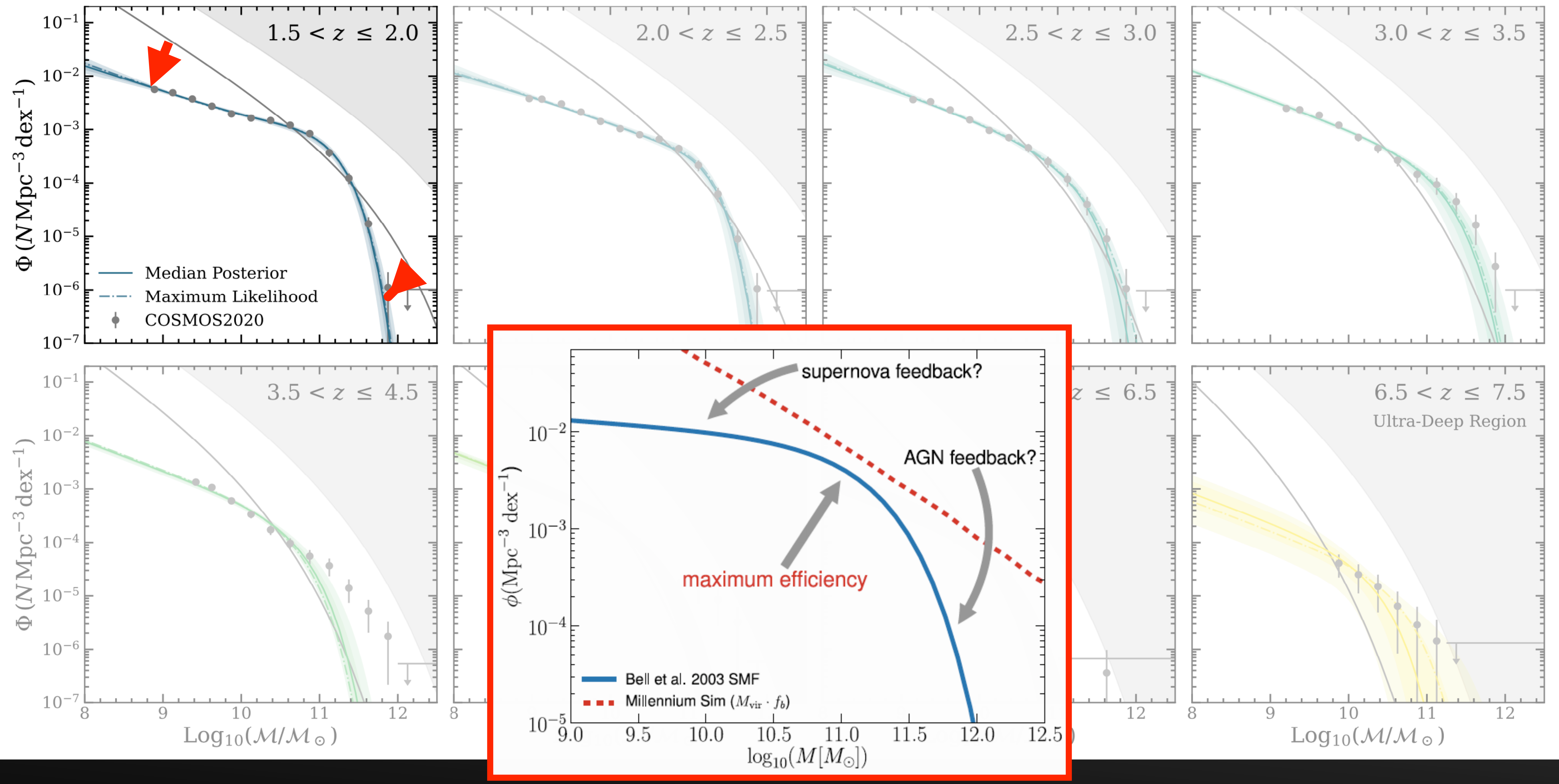
DM halos and galaxies mass functions



Halo mass function x f_b

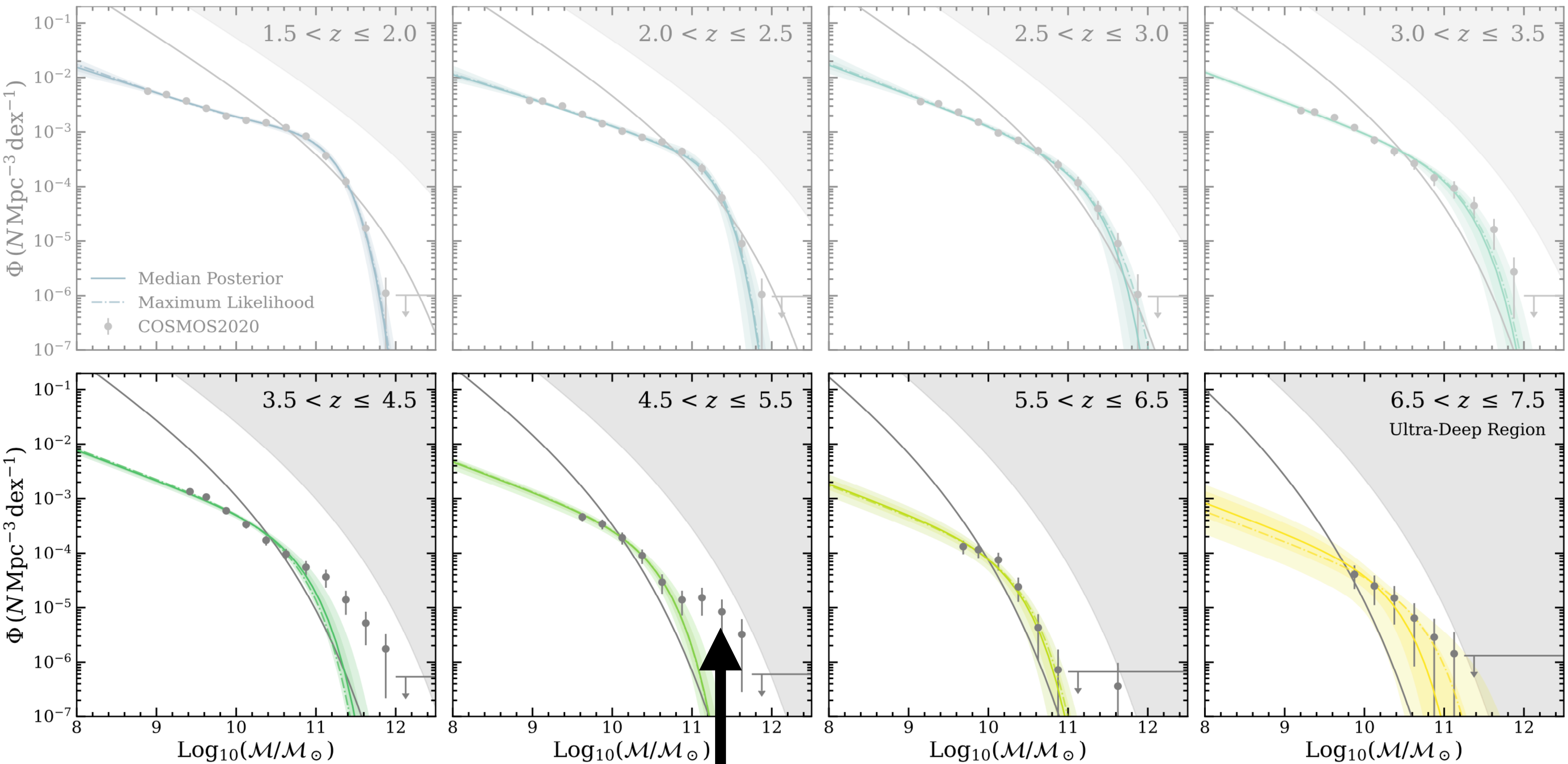
Halo mass function x 0.018

DM halos and galaxies mass functions



SN and AGN feedbacks already active by 1.5<z<2

DM halos and galaxies mass functions



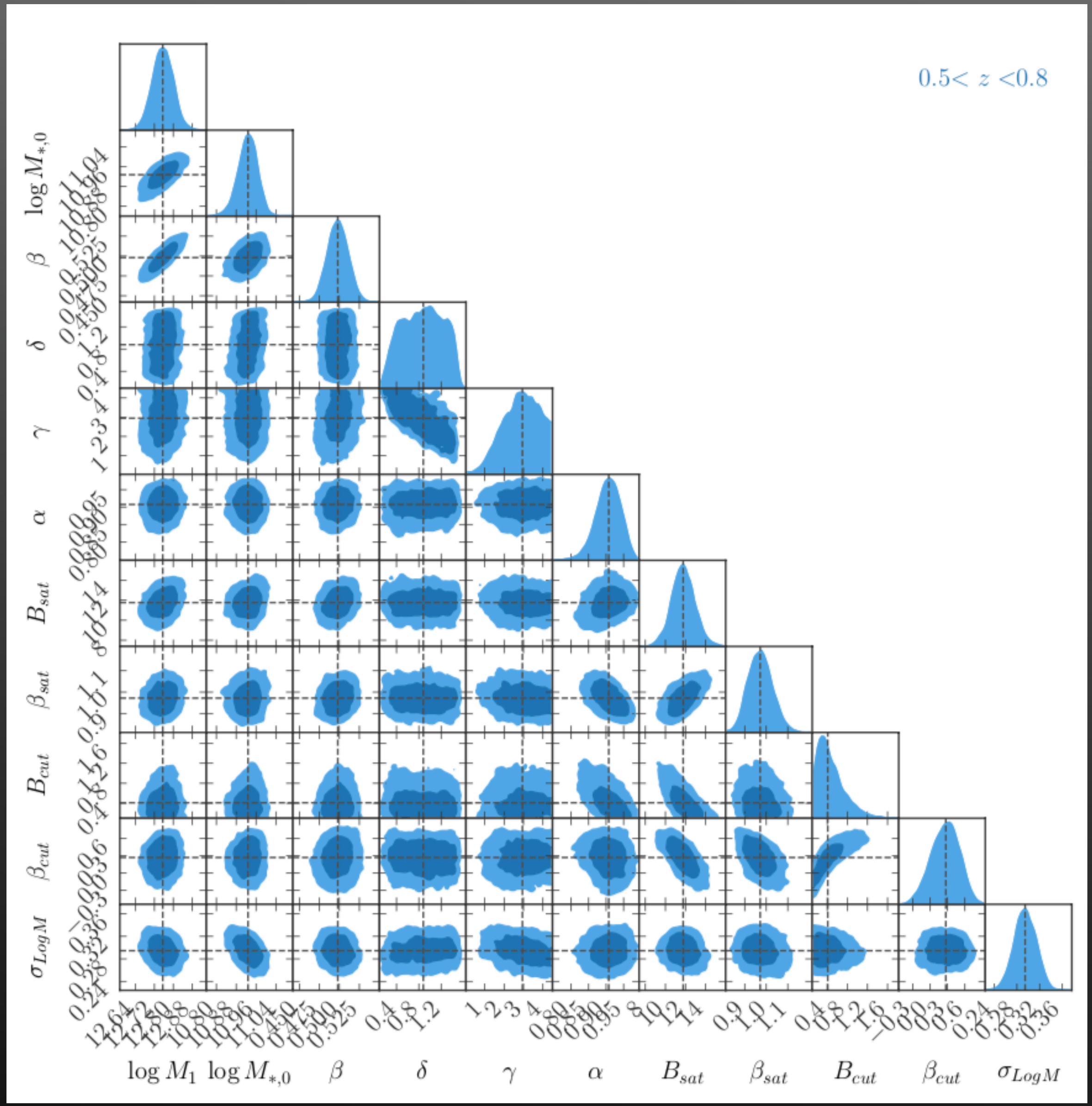
Change in the high mass regime? (AGN feedback, cold accretion)

Fit observables with a phenomenological model

Shuntov et al. 2022, A&A, 664, 61

Model describing the number of central and satellite galaxies as a function of DM halo mass and above a stellar mass threshold

Fit stellar mass function and angular clustering

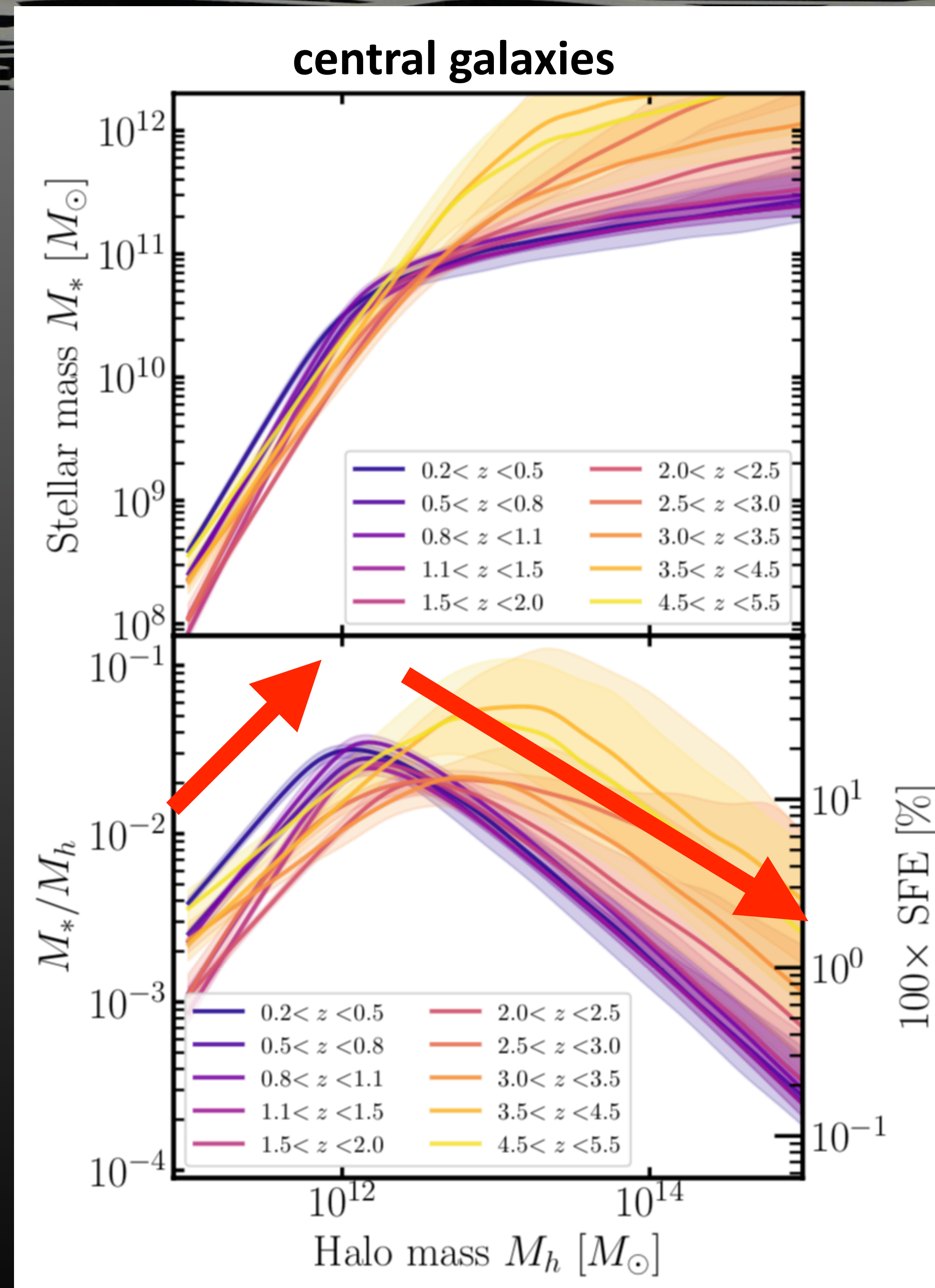


11 free parameters

Stellar-to-halo mass relation (SHMR) out to z<5.5

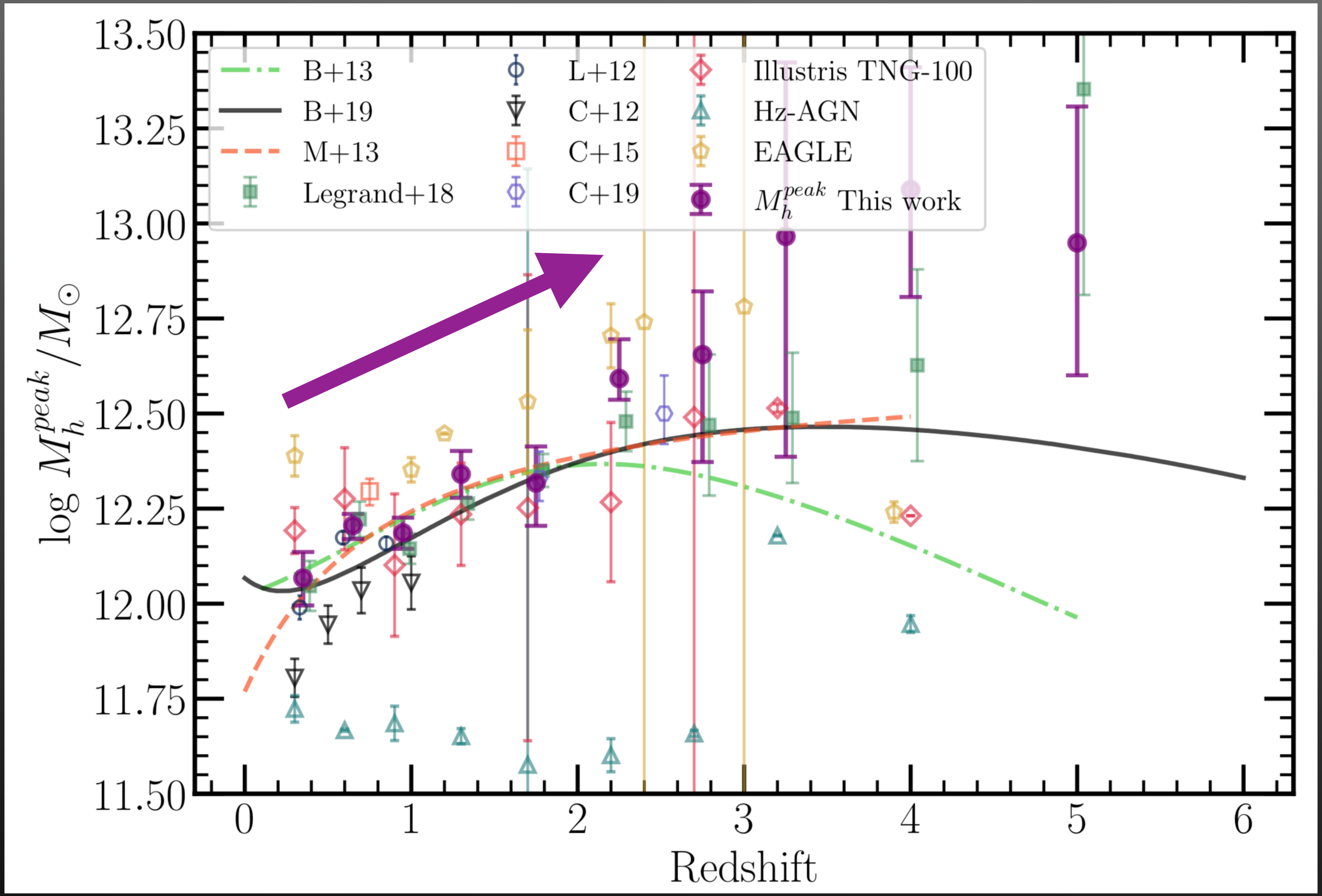
Star formation efficiency varies with halo mass

Maximum efficiency at $M_h \sim 10^{12}\ M_\odot$

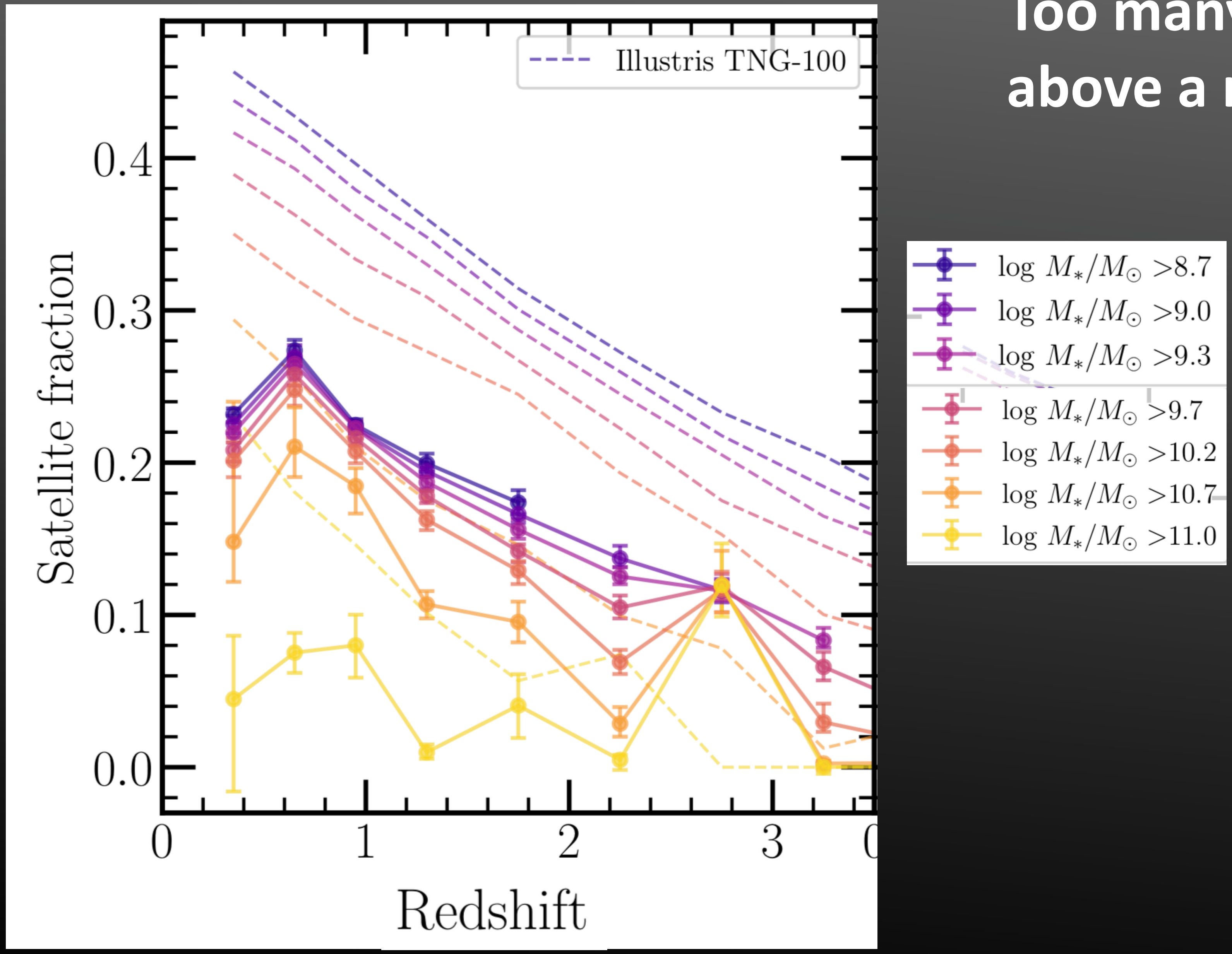


Evolution of the SHMR peak

Star formation efficiency shifts toward more massive halos in the early Universe

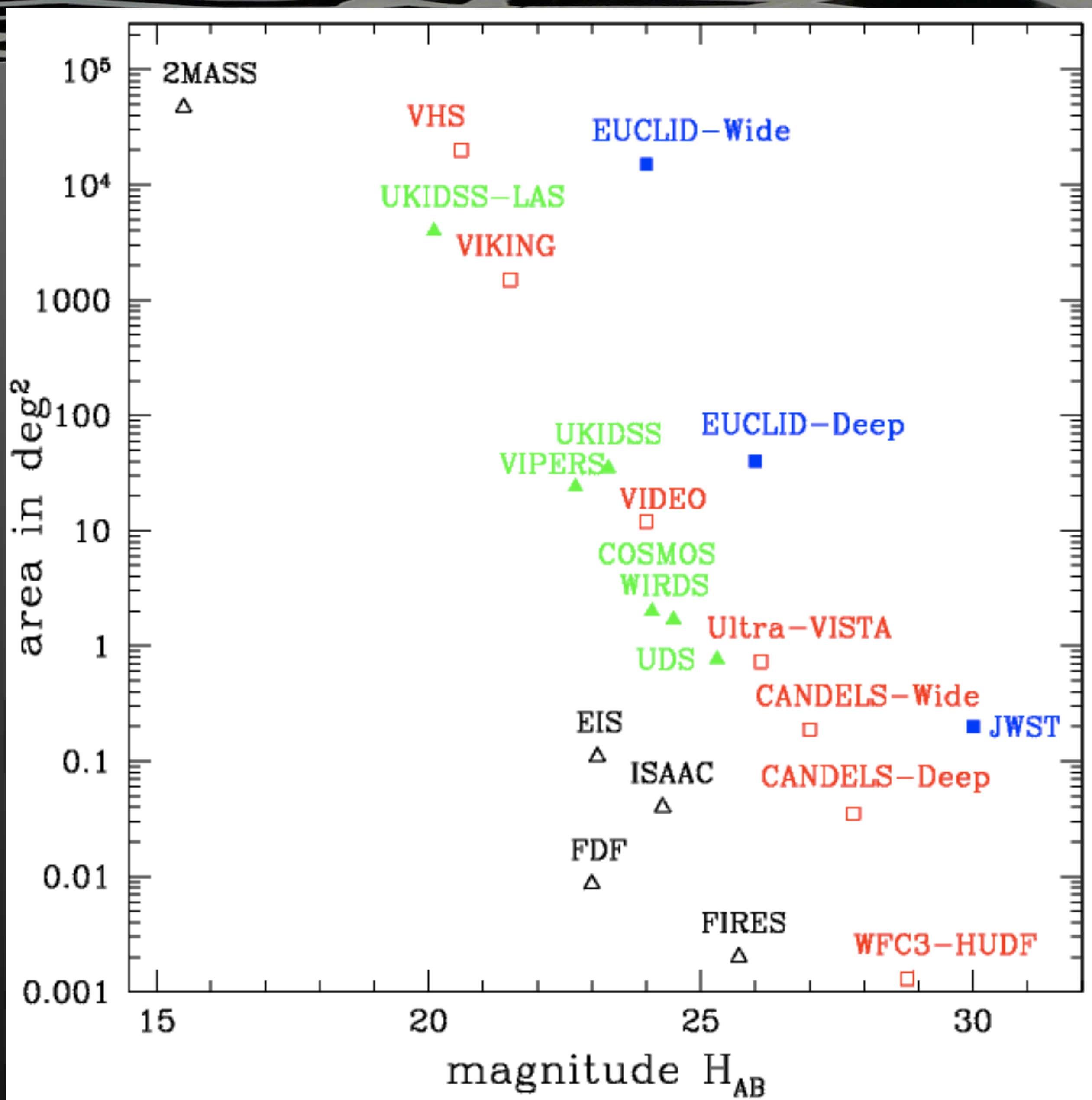


Satellite galaxies



Too many satellites in simulation above a mass threshold

Next ?

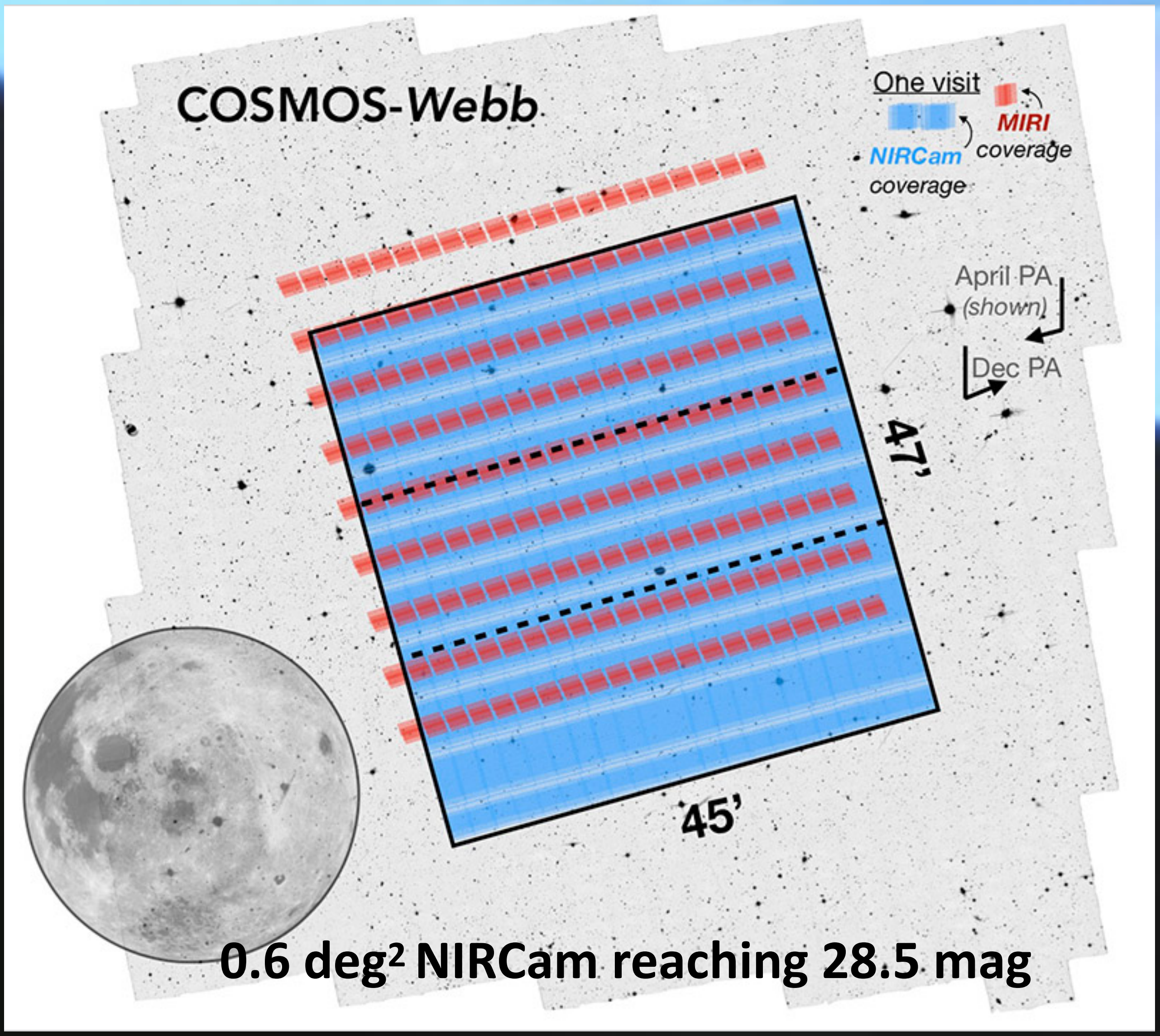


Now !!

Next year

COSMOS will be observed by both satellites

Galaxy evolution with JWST



COSMOS-Web, Cycle 1, 207h

- First galaxies and reionization
- Rise of quiescent galaxies, quenching
- Linking dark matter with visible, weak lensing

Summary

COSMOS2020

Two photometric catalogues with > 1 million of sources

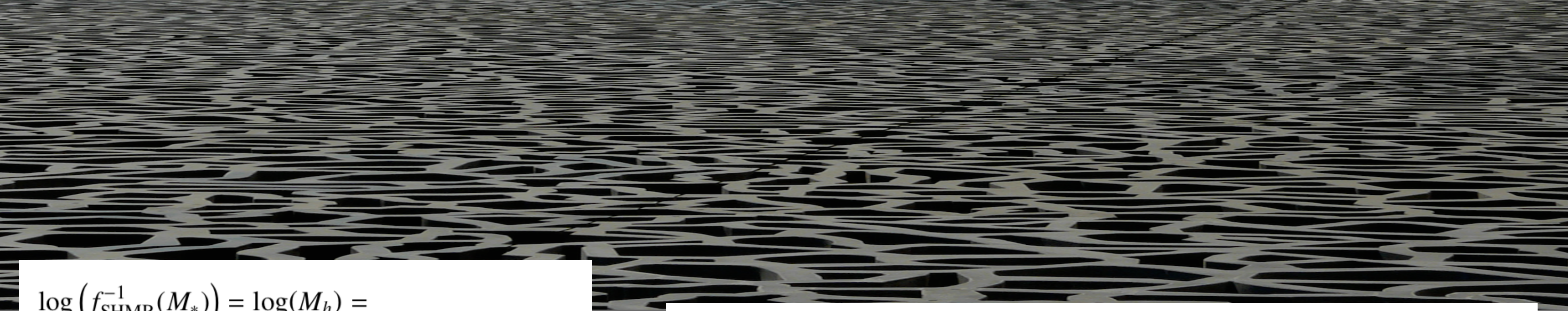
Associated photometric redshifts and stellar masses

https://cosmos2020.calet.org/catalogues/

Total stellar mass function characterized over 12.5 Gyr, with a single field and methodology

Connection with dark matter halos

- **No contradiction with ΛCDM**
- **Increasing efficiency of the star-formation in massive halos as z increases**
- **Feedback plays a crucial role in shaping this connection**
- **Too many satellites in cosmological simulation**



$$\log\left(f^{-1}_{\mathrm{SHMR}}(M_*)\right) = \log(M_h) =$$
$$\log(M_1) + \beta\log\left(\frac{M_*}{M_{*,0}}\right) + \frac{\left(\frac{M_*}{M_{*,0}}\right)^{\delta}}{1+\left(\frac{M_*}{M_{*,0}}\right)^{-\gamma}} - \frac{1}{2}.$$

$$\left\langle N_{\mathrm{cent}}\left(M_h| > M_*^{\mathrm{th}}\right)\right\rangle =$$
$$\frac{1}{2}\left[1 - \mathrm{erf}\left(\frac{\left[\log\left(M_*^{\mathrm{th}}\right) - \log(f_{\mathrm{SHMR}}(M_h))\right]}{\sqrt{2}\,\sigma_{\mathrm{Log}M_*}}\right)\right].$$

$$\left\langle N_{\mathrm{sat}}\left(M_h| > M_*^{\mathrm{th}}\right)\right\rangle =$$
$$\left\langle N_{\mathrm{cent}}\left(M_h| > M_*^{\mathrm{th}}\right)\right\rangle \left(\frac{M_h}{M_{\mathrm{sat}}}\right)^{\alpha_{\mathrm{sat}}} \exp\left(\frac{-M_{\mathrm{cut}}}{M_h}\right).$$

$$\frac{M_{\mathrm{sat}}}{10^{12}M_\odot} = B_{\mathrm{sat}}\left(\frac{f^{-1}_{\mathrm{SHMR}}(M_*^{\mathrm{th}})}{10^{12}M_\odot}\right)^{\beta_{\mathrm{sat}}},$$
$$\frac{M_{\mathrm{cut}}}{10^{12}M_\odot} = B_{\mathrm{cut}}\left(\frac{f^{-1}_{\mathrm{SHMR}}(M_*^{\mathrm{th}})}{10^{12}M_\odot}\right)^{\beta_{\mathrm{cut}}}.$$